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Tentative General Lighting Safety Orders

Issued by the
Industrial Accident Commission
of the
State of California

525 MARKET STREET, SAN FRANCISCO
UNION LEAGUE BUILDING, LOS ANGELES

Public Hearings on these Tentative Safety Orders will be held as follows, beginning at 10 a.m.: On June 5, 1919, in Room 307, 525 Market Street, San Francisco; on June 12, 1919, in Room 405, Union League Building, Los Angeles.

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INDUSTRIAL ACCIDENT COMMISSION
OF THE STATE OF CALIFORNIA

525 Market Street, San Francisco
423 Union League Building, Los Angeles

A. J. PILLSBURY, Chairman.
WILL J. FRENCH,
MEYER LISSNER,
Commissioners.

JOHN R. BROWNELL,
Superintendent of Safety.

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MAY 27 1919

ALLIED PRINTING TRADES UNION LABEL COUNCIL SACRAMENTO

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SUMMARY OF THE SAFETY PROVISIONS

of the

Workmen's Compensation, Insurance and Safety Act.

Being Chapter 176 of the Laws of 1913 as Amended by Chapter 607 of the Laws of 1915, and Chapter 586 of the Laws of 1917.

Sections 33 to 54, inclusive, of the Workmen's Compensation, Insurance and Safety Act give the Industrial Accident Commission power to make and enforce safety orders, rules and regulations, to prescribe safety devices, and to fix safety standards. It also empowers the Commission to appoint advisers who shall, without compensation, assist the Commission in establishing standards of safety. The Commission may adopt and incorporate in its general orders such safety recommendations as it may receive from such advisers.

The Commission, carrying out its plan of obtaining the best practical ideas to incorporate in its Safety Orders, asked various interests to serve on a committee to draft Tentative General Lighting Safety Orders.

COMMITTEE ON TENTATIVE GENERAL LIGHTING SAFETY ORDERS.

ROMAINE W. MYERS (chairman), illuminating engineer, representing the National Council of Defense, Divisional Committee on Lighting.

L. E. VOYER (vice chairman), illuminating engineer, General Electric Company, representing the Association of Electrical Manufacturers and the Lighting Fixture Association.

W. W. HANSCOM, electrical and mechanical engineer, representing the National Electric Light Association, Pacific Coast Section.

SMITH O'BRIEN, architect, representing the American Institute of Architects.

R. H. FENKHAUSEN, electrical engineer, Bethlehem Shipbuilding Corporation, Union Plant, representing the American Institute of Electrical Engineers.

DANIEL C. MURPHY, president California State Federation of Labor.

PAUL SCHARRENBERG, secretary-treasurer California State Federation of Labor.

R. S. PRUSSIA, illuminating engineer, Westinghouse Lamp Company, representing the Association of Electrical Manufacturers.

MILES F. STEEL, Benjamin Electric Manufacturing Company, representing the Association of Electrical Manufacturers.

S. J. LISBERGER, engineer of electrical distribution, Pacific Gas and Electric Company, representing the Pacific Coast Gas Association.

CHAS. M. MASSON, illuminating engineer, Southern California Edison Company, representing the Illuminating Engineering Society.

CONSTANT MEESE, Meese & Gottfried Company, representing the San Francisco Chamber of Commerce.

F. DOHRMANN, JR., Nathan-Dohrmann Company, representing the San Francisco Chamber of Commerce.

HARRY GORMAN, field agent, representing the Bureau of Labor Statistics.

H. B. WOODILL, president Woodill & Hulse Electric Company, Inc., representing the Merchants and Manufacturers Association of Los Angeles.

W. A. CHOWEN, manager California Inspection Rating Bureau, representing the Casualty Underwriters Board of California.

D. AYRE, superintendent inspection department, California Inspection Rating Bureau, representing the Casualty Underwriters Board of California.

HAROLD MESTRE, representing the Industrial Welfare Commission.

R. L. ELTRINGHAM, electrical engineer, representing the Industrial Accident Commission.

JOHN R. BROWNELL (secretary), superintendent of safety, Industrial Accident Commission.

Acknowledgment is made of the assistance rendered by the Illuminating Engineering Society in the preparation of these Tentative Orders, and for the use of the various cuts which they kindly loaned.

TENTATIVE GENERAL LIGHTING SAFETY ORDERS.

Order 1500. **Definitions.**

(*a*) *Candle* (or candlepower) means the unit of luminous intensity maintained by the national laboratories of the United States, France and Great Britain.

(*b*) *Lumen* means the unit of luminous flux, and is the quantity of light necessary to produce an average intensity of illumination of one foot-candle over an area of one square foot.

(*c*) *Foot-candle* means the unit of illumination equal to one lumen per square foot. It is the lighting effect produced upon an object by a lamp of one candlepower at a distance of one foot.

(*d*) *Photometer* means a standardized instrument suitable for making illumination measurements.

(*e*) *Lamp* means that part of the lighting equipment from which the light originates.

(*f*) *Local lamps* (or lighting) means lighting units located close to the work, and intended to illuminate only a limited area about the work.

(*g*) *Overhead lamps* (or lighting) means lighting units installed above ordinary head-level to secure a general illumination over a considerable area.

(*h*) *Brightness* means the intensity of light per unit area emitted from, or reflected by, a body; and in these Orders is expressed in candlepower per square inch.

(*i*) *Glare* means any brightness within the field of vision of such a character as to cause discomfort, annoyance, interference with vision, or eye fatigue.

(*j*) *Eyestrain* means a physiological condition of the eye resulting in discomfort, poor vision, or fatigue.

(*k*) *Shaded* means that the lamp is equipped with a reflector, shade, enclosing globe, or other accessory for reducing the brightness in certain directions, or otherwise altering or changing the distribution of light from the lamp.

(*l*) *Illumination* means the quantity of light thrown upon an object by a luminous body; it is measured in foot-candles per square foot of area.

(*m*) *Intensity of illumination* means the foot-candles per square foot of area.

(*n*) *Foot-candles at the work* means the intensity of illumination on the object upon which work is being performed.

(o) *Foot-candles at floor-level* means the intensity of illumination on the floor of the space specified.

Order 1501. **General Requirements.**

(*a*) Working or traversed spaces in buildings or grounds of places of employment shall be supplied during the time of use, with either natural or artificial light in accordance with the following Orders (1502–1509).

Order 1502. **Natural Lighting.**

(*a*) Windows, skylights or other roof-lighting construction of buildings shall be arranged with the glass area so apportioned that at the darkest part of any working space, when normal exterior daylight conditions obtain (sky brightness of 1.50 candlepower per square inch) there will be available a minimum intensity equal to twice that of Order 1503, otherwise artificial light of intensities specified in Order 1503 shall be provided.

(*b*) Awnings, shades, diffusive or refractive window glass shall be used for the purpose of improving daylight conditions or for the avoidance of eyestrain wherever the location of the work is such that the worker must face large window areas through which excessively bright light may at times enter the building.

NOTE.—The intensity requirements for adequate day lighting are much higher than those for adequate night lighting, because in general under daylight conditions the light reaching the eye from all surroundings in the field of vision is much brighter than at night, and hence a correspondingly more intense light must fall on the object viewed.

Order 1503. **Artificial Light.**

(*a*) When the natural light is less than twice the minimum permissible intensities of illumination set forth in the following table, artificial light shall be supplied and maintained in accordance with the table.

NOTE.—See Appendix for intensities recommended for best working conditions.

	Foot-candles at the floor level
1. Roadways and yard thoroughfares	0.02
2. Storage spaces, stairs, stairways, halls, hallways, passageways, aisles, exits and elevator entrances	0.25
3. Water-closet compartments, toilet rooms, washrooms, dressing rooms and elevator cars	0.50

	Foot-candles at the work
4. Work not requiring discrimination of detail, such as handling material of a coarse nature, and performing operations not requiring close visual application	0.50
5. Rough manufacturing requiring discrimination of detail, such as rough machining, rough assembling, rough bench work, also work in basements of mercantile establishments requiring discrimination of detail	1.00
6. Rough manufacturing requiring closer discrimination of detail, such as machining, assembly and bench work, also work in basements of mercantile establishments requiring closer discrimination of detail, intermediate between 5 and 7	2.00
7. Fine manufacturing, such as fine lathe work, pattern and tool making, also office work, such as accounting and typewriting	3.00
8. Special cases of fine work, such as watchmaking, engraving and drafting	5.00
9. Processes otherwise safeguarded in which light is detrimental	0.00

NOTE.—Some exceptions to the intensity rule:

(*a*) There are some operations that are performed in comparative darkness, as for example, photographic processes in the dark room.

(*b*) There are some operations that are best observed by their own light, as in parts of the process of working glass.

(*c*) Some operations are best observed by the "silhouette" method of lighting in which the work is seen against a lighted background in a comparatively dark room, as in some processes of working with dark threads and lamp filaments.

In all such cases in which work is of necessity carried on in comparative darkness, special precautions should be taken to properly safeguard the workmen.

Order 1504. **Measurements.**

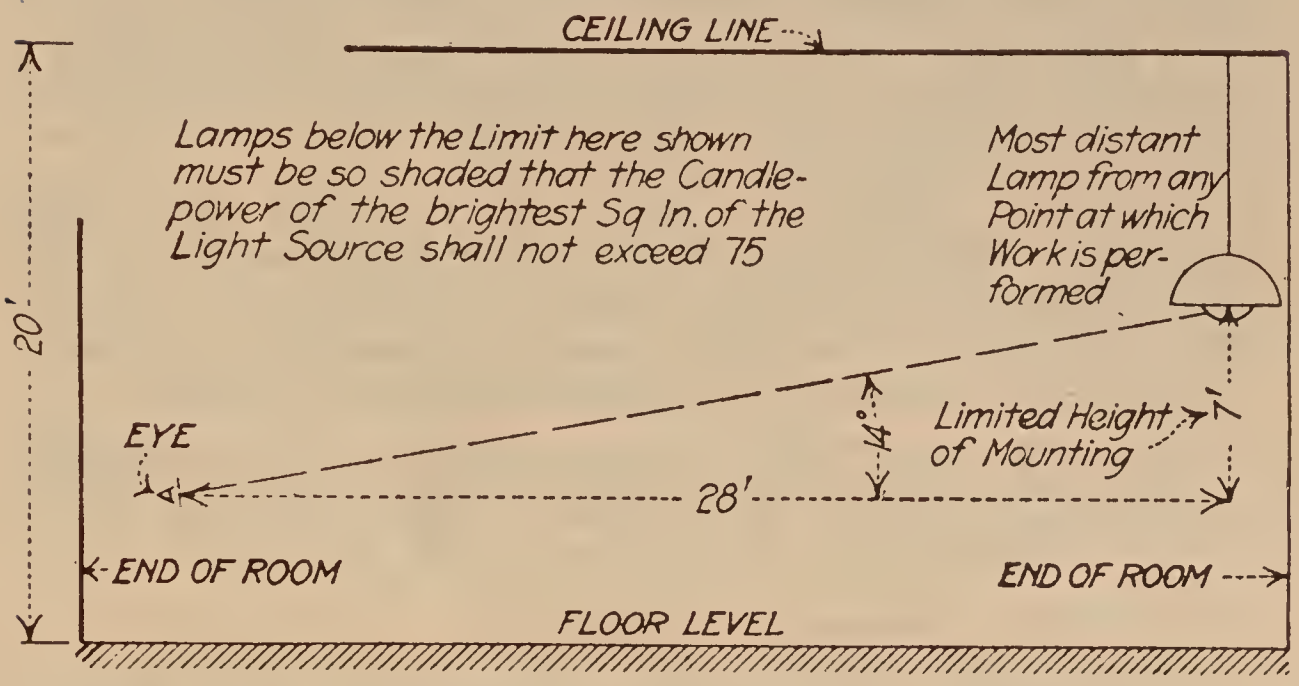
(*a*) For the purpose of light measurements, a standardized photometer, certified by the Industrial Accident Commission of the State of California, shall be used, and such measurements shall be made at the locations specified in the table.

Order 1505. **Shading of Lamps for Overhead Lighting.**

(*a*) Lamps suspended at elevations above eye level less than one-quarter their distance from any positions at which work is performed, must be shaded in such a manner that the

intensity of the brightest square inch of visible light source shall not exceed seventy-five candlepower.

NOTE.—The following diagram illustrates the application of the above rule, the distances being explanatory and representing the ratio between the height of the lamp above the eye level and its horizontal distance from the eye.



Exception. Lamps suspended at elevations greater than twenty feet above the floor are not subject to this requirement.

NOTE 1.—Glare from lamps or unduly bright surfaces produces eye-strain and increases the accident hazard. The brightness limit specified in this Order is an absolute maximum. Very much lower brightness limits are necessary in many interiors illuminated by overhead lamps, if the illumination is to be satisfactory. In some cases the maximum brightness should not exceed that of the sky (two to three candlepower per square inch).

NOTE 2.—Where the principal work is done on polished surfaces, such as polished metal, celluloid, varnished wood, etc., it is desirable to limit the brightness of the lamps in all downward directions to the amount specified in this Order.

NOTE 3.—For method of measuring brightness, see Appendix, paragraph 86.

Order 1506. **Shading of Lamps for Local Lighting.**

(*a*) Lamps for local lighting must be shaded in such a manner that the intensity of the brightest square inch presented to view from any position at which work is performed, shall not exceed three candlepower.

NOTE.—In the case of lamps used for local lighting, at or near eye level, the limits of permissible brightness are much lower than for lamps used for overhead lighting, because the eyes are more sensitive to strong light received from below, and because such light sources are more constantly in the field of view.

Order 1507. **Distribution of Light on the Work.**

(*a*) The reflectors or other accessories, mounting heights and spacings employed with lamps shall be such as to secure a reasonably uniform distribution of illumination, avoiding objectionable shadows and sharp contrasts of brightness. If local lighting is used, there shall be employed in addition a moderate intensity of overhead lighting, with a minimum of not less than one-fourth ($\frac{1}{4}$) foot-candle.

Exception. Where the light from the local lamps falls principally upon surfaces which are white or nearly so, and the ceilings and walls of the rooms are light, there is often a sufficient general illumination received indirectly by reflection to obviate the necessity of additional overhead lighting.

NOTE.—When local lighting is used as the sole source of illumination of an interior, the field of illumination from each lamp is in contrast to the surrounding darkness, thereby causing eyestrain and increasing the accident hazard.

Order 1508. **Emergency Lighting.**

(*a*) Emergency lights shall be provided in all workspace aisles, stairways and passageways; at all exits, and on all outside landings of fire-escapes or other structures used as regular or emergency means of egress to provide for reliable operation when, through accident or other cause, the regular lighting is extinguished.

NOTE 1.—It is the intention of this Order to guard against accident due to the failure of the regular lighting system, by providing sufficient illumination to enable the occupants to:

(*a*) Avoid contact with moving machinery and other danger points until the regular lighting is again placed in operation.

(*b*) To vacate the building safely and expeditiously when this is necessary because of fire or other causes.

NOTE 2.—Emergency lighting may be installed in various ways. The method to be employed depends upon the size of the premises, the extent of the hazards of employment, and the means available for supplying such emergency lighting.

(*b*) Emergency lighting systems, including all supply and branch lines, shall be entirely independent of the regular lighting system and shall be lighted concurrently with the regular lighting system and remain lighted throughout the period of the day during which artificial light is required or used.

(*c*) Emergency lighting, where required, shall have a minimum intensity of one-fourth ($\frac{1}{4}$) foot-candle.

(*d*) Emergency lighting systems shall, where the nature of the hazard is such as to require it, be supplied from a source independent of the regular lighting system wherever possible. This source of supply and controlling equipment shall be such as to insure the reliable operation of the emergency lighting system when, through accident or other cause, the regular lighting system is extinguished. Where a separate source of supply can not be obtained for the emergency lighting the feed for emergency lights must be taken from a point on the street side of the service equipment. Where source of supply for the regular lighting system is an isolated plant within the premises, an auxiliary lighting system of sufficient capacity to supply all emergency lighting must be installed from some other source, or suitable storage battery; or separate generating unit may be considered the equivalent of such service.

Order 1509. **Switching and Control Apparatus.**

(*a*) Switches or other controlling apparatus shall be so installed that pilot or night lights may be controlled from a point at the main entrance, and other easily accessible points. Pilot or night lights may be a part of the emergency lighting system.

(*b*) All switching and control apparatus on emergency, pilot and night lights shall be plainly labeled for identification.

NOTE.—The purpose of this Order is to make it possible for the night watchman or other qualified persons to turn on enough lamps, when entering any portion of the premises at night, to enable them to safely see their way around without the need of a lantern or flashlight.

APPENDIX.

GENERAL INFORMATION AND SUGGESTIONS.

1. The foregoing Orders give in the briefest possible form the essentials of proper and adequate lighting for factories, mills and other work places, general information with detailed discussion of the methods of applying the Orders being presented in this Appendix.

2. When adequate and satisfactory illumination is substituted for the all too prevalent poor illumination in factories, mills and other work places, the results obtained are mutually beneficial to the employees, the employers, and the country as a whole. Under proper illumination conditions, the health, contentedness, safety and skill of the employees are maintained at a high standard, the output is increased in quantity and improved in quality, while there is a proportional reduction in the cost of each unit of finished products when it reaches the public.

3. While it is desirable to have adequate light over the working areas, it is absolutely essential for the proper results to eliminate or minimize the light which otherwise would pass directly from the lamps to the eyes of the workers; that is, one must avoid *glare* which is not only fatiguing to the eye but also conducive to the incorrect estimation of sizes and locations of objects in the field of view.

4. Glare effects may be caused not only by the light reaching the eye directly from the sources having a brightness greatly in excess of that of the objects viewed, but they may be produced by excessive reflection from the objects within view. In factory lighting each lamp should be so located that the eye does not see it in the ordinary course of work, and so shaded or covered that brilliant reflections are avoided. The desired result can be obtained by putting over the lamp an open shade which screens it and reflects downward much of the light which would otherwise be of either no value or actually detrimental. Another way of accomplishing the same result is to surround the lamp with a diffusing globe dense enough not to reveal the form of the actual light source within, but to give the effect of the light pouring from the globe as a whole. Specific suggestions for various locations are contained in this Appendix.

5. In the following descriptive matter may be found the elements of good illumination versed in such manner that it

can be understood readily by the nontechnical mind. A perusal of this subject will convince one that, aside from the humanitarian standpoint, the expense incurred in obtaining satisfactory lighting will, in practically all cases, result in good financial returns.

6. *Minimum and desirable illumination.* The minimum foot-candles in Order 1503 specify the lowest illumination with which the employee can be properly safeguarded against accident. It is to the advantage of the employer to provide the corresponding intensities of modern practice listed in the following table of desirable illumination, as such provision results in reduced eyestrain, greater accuracy of workmanship, increased production and less spoilage.

Desirable Illumination.

	Foot-candles at floor level—modern practice	Corresponding minimum—Order 1503
1. Roadways and yard thoroughfares	0.05 to 0.25	0.02
2. Storage spaces	0.50 to 1.00	0.25
3. Stairs, stairways, halls, hallways, passageways, aisles, exits, elevator entrances and elevator cars	1.00 to 2.00	0.25–0.50
4. Work not requiring discrimination of detail	1.00 to 2.00	0.50
5. Rough manufacturing requiring discrimination of detail	2.00 to 4.00	1.00
6. Rough manufacturing requiring closer discrimination of detail	3.00 to 6.00	2.00
7. Fine manufacturing, accounting, typewriting	4.00 to 8.00	3.00
8. Special cases of fine work	7.00 to 15.00	5.00

7. **Table of Recommended Intensities for Detailed Operations and Processes. (Expressed in foot-candles.)**

Classification.	
Assembling.	
Rough assembling	2–4
Medium assembling	3–6
Fine assembling	4–8
Extra fine assembling	7–15

Classification.	
Automobile manufacturing.	
(See machine shops, paint shops, woodworking shops, etc.)	
Bakeries.	
Mixing and baking	3–6
Banks.	
Clerical and private offices	4–8
Desk and cage lighting	4–8
General illumination	1–2
Barber shops	4–8
Boiler, engine rooms and power houses.	
Boiler rooms	2–4
Coal and ash handling	2–4
Engine rooms	3–6
Auxiliary equipment	2–4
Oil switch and transformer rooms	3–6
Switchboards	3–6
Storage battery rooms	2–4
Brewing, distilling and bottling.	
Beer boiling	2–4
Bottling	3–6
Clearing or resting and fermenting	1–2
Cool ship	1–2
Keg washing	3–6
Keg filling	3–6
Button manufacturing.	
Grading machines, wet and dry polishing	1–2
Grinding machines, cutting blanks and shells, carding buttons, hand turning, automatic machines	2–4
Sorting of waste, sorting for thickness	3–6
Grading for color and defects	7–15
Candy making.	
Cooking over furnaces	3–6
Cooling slabs	3–6
Cream beater machines	3–6
Dipping (hand)	3–6
Dipping (machine)	3–6
Moulding	3–6
Revolving pan	3–6
Spinning bench	3–6
Weights and measures	3–6
Wrapping and packing	3–6
Canning and preserving.	
Cooking	3–6
Assorting, cleaning, cutting and peeling	3–6
Hand filling	3–6
Machine filling	3–6

Classification.		
Chemical works.		
Furnaces		2–4
Tanks or cooking, extractors, percolators, nitrators		3–6
Generators and stills		3–6
Drying		2–4
Evaporators		3–6
Filtration		3–6
Grinding		3–6
Crystallizing		3–6
Bleaching		3–6
Electrolytic cells		3–6
Clay products and cements.		
Enameling		3–6
Grinding		2–4
Filter press rooms		2–4
Moulding and pressing		3–6
Cleaning and trimming		3–6
Coloring and glazing		4–8
Kiln rooms		2–4
Cloth products.	Light goods.	Dark goods.
Cutting	4–8	7–15
Sewing (machine)	4–8	7–15
Sewing (hand)	4–8	7–15
Pressing	4–8	7–15
Inspecting	4–8	7–15
Cloth treating (oilcloth, etc.)	4–8	7–15
Dairy products.		
Separators, evaporators, churns, moulds and presses		3–6
Pasteurizing		3–6
Bottling, canning and labeling		3–6
Ice cream freezers		3–6
Depots.		
Baggage rooms		1–2
Dining rooms		3–6
General offices		4–8
Waiting rooms		2–4
Loading platforms		1–2
Draughting rooms		7–15
Electric manufacturing.		
Coil and armature winding		4–8
Mica working		4–8
Insulation moulding		4–8
Other insulating processes		4–8
Storage battery moulding		3–6
Lamp manufacturing		7–15
Wire insulating		4–8

Classification.	
Fertilizer manufacturing.	
Cookers, pressers, fertilizer dryers, fertilizer mills	2–4
Forge shops and welding.	
Rough forging	2–4
Fine forging	3–6
Drop forging	3–6
Foundries.	
Rough moulding	2–4
Fine moulding	3–6
Core making	3–6
Charging floor	2–4
Tumbling and cleaning	2–4
Glass works.	
Mix room	2–4
Furnace room	2–4
Casting and lehr	2–4
Grinding	3–6
Fine grinding and polishing	4–8
Glass-blowing machines	2–4
Cutting glass to size	3–6
Glass cutting (cut glass)	7–15
Beveling	4–8
Silvering	3–6
Inspecting	7–15
Etching and decorating	4–8

Glove manufacturing.	Light goods.	Dark goods.
Sorting	4–8	7–15
Cutting	3–6	4–8
Stitching	4–8	7–15
Trimming and inspecting	4–8	7–15
Pressing	3–6	4–8
Knitting	3–6	4–8
Grinding, Buffing and polishing.		
Rough work		2–4
Medium work		3–6
Fine work		4–8
Halls, stairways, passageways and aisles		1–2

Hat manufacturing.	Light goods.	Dark goods.
Forming, sizing, pouncing, flanging, finishing and ironing	3–6	4–8
Dyeing and stiffening	2–4	3–6
Braiding	2–4	3–6
Cleaning and refining	2–4	3–6
Sewing	4–8	7–15

Classification.	
Hospitals.	
Corridors	0.5
Wards, general (supplemented by local)	0.5
Wards, with no local lighting	1–3
Laboratories	3–6
Operating tables	25–40
(See boiler and engine rooms, laundries, kitchens, dining rooms, storage spaces, etc.)	
Hotels.	
Kitchens	2–4
Dining rooms	3–6
(See engine and boiler rooms, offices, storage spaces, stairways, passageways, laundries, etc.)	
Ice making	2–4
Inspecting.	
Rough inspecting	2–4
Medium inspecting	3–6
Fine inspecting	4–8
Extra fine inspecting	7–15
Jewelry and watch manufacturing.	
Bench work and extra fine machine work	7–15
Machine work	7–15
Stamping	7–15
Engraving	7–15
Jewel working	7–15
Laundries and dry cleaning.	
Sorting and marking	3–6
Washing	2–4
Mangles and machine ironing	3–6
Pressing and hand ironing	3–6
Dry and steam cleaning	3–6
Leather manufacturing.	
Cleaning, tanning, stretching, etc.	2–4
Cutting, fleshing and stuffing	3–6
Finishing and scarfing	4–8

Leather working.	Light goods.	Dark goods.
Grading and matching	4–8	7–15
Cutting and scarfing	4–8	4–8
Sewing	4–8	7–15
Pressing and winding	3–6	4–8

Libraries	3–6
(See other classifications relating to corresponding quarters.)	
Locker, toilet and wash rooms	2–4

Classification.	
Machine shops.	
Rough bench and machine work	2–4
Medium bench and machine work	3–6
Fine bench and machine work	4–8
Extra fine bench and machine work	7–15
Automatic machines (ordinary)	3–6
Automatic machines (fine)	4–8
Meat packing.	
Slaughtering	2–4
Cleaning and cutting	3–6
Cooking	3–6
Grinding and packing	3–6
Canning	3–6
Milling and grain food products.	
Cleaning	2–4
Grinding or rolling	2–4
Baking or roasting	3–6
Offices	4–8
Packing.	
Rough	3–6
Fine	4–8
Paint manufacturing	2–4
Paint shops.	
Dipping or spraying	3–6
Rubbing	3–6
Firing	2–4
Hand painting and finishing, ordinary	3–6
Hand painting and finishing, fine	4–8
Hand painting and finishing, extra fine (automobile bodies, piano cases, etc.)	7–15

Paper box manufacturing.	Light goods.	Dark goods.
Cutting	2–4	3–6
Machine folding	2–4	3–6
Hand folding	2–4	3–6
Pasting and assembling	2–4	3–6
Paper manufacturing.		
Beaters		2–4
Calendering		3–6
Machine		3–6
Grinding		2–4
Finishing, cutting and trimming		4–8
Plating.		
Plating		3–6
Polishing and burnishing		3–6

Classification.	
Printing industries.	
Linotype and monotype	7–15
Typesetting	7–15
Composing stone	7–15
Matrixing and casting	3–6
Miscellaneous machines	3–6
Proofreading	4–8
Presses, job and small automatic	3–6
Presses, rotary, flat, bed, etc.	3–6
Lithographing	4–8
Electrotyping	4–8
Engraving	7–15
Receiving and shipping	2–4
Restaurants. (See Hotels.)	
Roadways and yard thoroughfares	0.05–0.25
Rubber manufacturing and products.	
Calendering	3–6
Grinding	3–6
Vulcanizing	3–6
Washing and compounding rolls	3–6
Sheet metal working.	
Bench work, ordinary	3–6
Bench work, fine	4–8
Punches, presses, shears, stamps and welders	4–8
Spinning	4–8
Miscellaneous machines	3–6
Shipbuilding.	
(See machine shops, sheet metal working, roadways, yard thoroughfares, woodworking, assembling, etc.)	

Shoe manufacturing.	Light goods.	Dark goods.
Inspecting and sorting raw material	4–8	7–15
Cutting	3–6	4–8
Stitching, machine	7–15	7–15
Stitching, hand	4–8	7–15
Lasting and welding	4–8	4–8
Hand turning	3–6	3–6
Miscellaneous bench and machine work	3–6	4–8

Soap manufacturing.	
Kettle houses	2–4
Framing	1–2
Cutting	2–4
Stamping, wrapping and packing	3–6
Soap chip	2–4
Soap powder	2–4
Filling and packing soap powder	3–6

Classification.	
Steel and iron mills, bar, sheet and wire products.	
Automatic machines	3–6
Charging floor	2–4
Casting floor	2–4
Soaking pits and reheating furnaces	2–4
Rolling mills	3–6
Shears, presses, punches and riveters	3–6
Rod mill	3–6
Wire drawing, coarse	3–6
Wire drawing, fine	4–8
Pickling and cleaning	2–4
Stone cutting.	
Machine cutting	2–4
Hand cutting	2–4
Carving	3–6
Polishing	3–6
Store and stock rooms.	
Rough stock	2–4
Medium stock	3–6
Fine stock	4–8
Stores.	
(Satisfactory store lighting requires that consideration be given so many different factors, such as location, color of finish, size and shape, location and character of displays, as to make it impossible to compile a complete list. The following tabulation is general, only, and it is recommended that expert advice be obtained where any doubt exists as to the proper allowances to be made.)	
Automobile showrooms	2–6
Art (light on exhibits)	5–10
Book	3–5
Baker	2–4
Butcher	2–4
China	2–3
Cigar	4–6
Clothing	4–7
Cloak and suit	4–7
Candy	3–6
Confectionery	3–5
Decorator	4–5
Department (see each department).	
Drug	2–4
Dry goods	4–7
Florist	2–3
Furniture	2–4
Furrier	5–8

Classification.	
Grocery	2–4
Haberdasher (men's furnishings)	5–7
Hardware	2–4
Hat	4–6
Jewelry	4–6
Millinery	4–6
Music	2–4
Notions	3–5
Piano	2–4
Rug racks	10–20
Shoe	2–4
Stationery	2–4
Tailor	4–6
Tobacco (see cigar).	
Schools.	
Auditoriums	2–4
Blackboards	3–5
Classrooms, study rooms, libraries, laboratories	3–6
Gymnasiums	3–6
Sewing, drafting	7–15
Shop work (rough)	2–4
Shop work (fine)	4–8
Stairways, corridors, toilets, hat and cloakrooms, etc.	1–2
Storage spaces	0.5–1
Telegraph.	
Operating	4–8
Telephone.	
Automatic exchanges	4–8
Manual exchanges	3–6
Testing.	
Rough	2–4
Medium	3–6
Fine	4–8
Extra fine	7–15

Textile mills. *Cotton—*	Light goods.	Dark goods.
Opening and lapping	2–4	2–4
Carding	2–4	2–4
Drawing frame	2–4	2–4
Roving, spooling, spinning, etc.	3–6	3–6
Warping	2–4	2–4
Slashing	2–4	2–4
Drawing in	3–6	3–6
Weaving	3–6	3–6
Dyeing	3–6	3–6

Classification.		
Silk—		
Winding	3–6	3–6
Throwing	3–6	3–6
Quilling and warping	3–6	4–8
Weaving	3–6	4–8
Dyeing	3–6	3–6
Finishing	3–6	4–8
Woolen—		
Picking	3–6	3–6
Washing and combing	3–6	3–6
Carding	2–4	2–4
Twisting	3–6	3–6
Dyeing	3–6	3–6
Drawing in	3–6	4–8
Warping	3–6	4–8
Weaving	4–8	7–15
Perching	7–15	7–15
Knitting machines, ordinary and nappers	3–6	3–6
Knitting machines, flat and others	4–8	4–8
Cordage mills	3–6	3–6
Tobacco products		3–6
Warehouses (See other classifications.)		2–4
Woodworking.		
Rough sawing (sawmills)		2–4
Sizing, planing, rough sanding, etc.		3–6
Machine woodworking, medium		3–6
Machine woodworking, fine		4–8
Bench work, medium		3–6
Bench work, fine		4–8
Fine sanding and finishing		4–8
Gluing and veneering		3–6
Cooperage		3–6

DAYLIGHT.

8. *Importance of daylight.* Adequate daylight facilities through large window areas, together with light, cheerful surroundings, are highly desirable and necessary features in every work place, and they should be supplied through the necessary channels not only from the humane standpoint, but also from the point of view of maximum plant efficiency. The unusual attention to gas and electric lighting in factories, mills and other work places during the past few years; the perfection of various lamps and auxiliaries by means of which an improved quality and quantity of lighting effects are

obtained; and the care which has been devoted to increasing the efficiency in various industrial operations—all go to emphasize the many advantages and economies that result from suitable and adequate window space as a means for daylight in the proper quantities and in the right directions during those portions of the day when it is available.

9. *Three considerations.* Three important considerations of any lighting method are sufficiency, continuity and diffusion. With respect to the daylight illumination of interiors, sufficiency demands adequate window area; continuity requires (*a*) large enough window area for use on reasonably dark days, (*b*) means for reducing the illumination when excessive due to direct sunshine, and (*c*) supplementary lighting equipment for use on particularly dark days and especially toward the close of winter days; diffusion demands interior decorations that are as light in color as practicable for ceilings and upper portions of walls, and of a dull or mat finish in order that the light which enters the windows or that which is produced by lamps, may not be absorbed and lost on the first object that it strikes, but that it may be returned by reflection and thus be used over and over again. Diffusion also requires that the various sources of light, whether windows, skylights or lamps, be well distributed about the space to be lighted. Light colored surroundings as here suggested result in marked economy, but their main object is perhaps not so much economy as to obtain a result that will be satisfactory to the human eye.

10. *Requirements.* The following requirements may now be listed for natural lighting:

1. The light should be adequate for each employee.

2. The windows should be so spaced and located that daylight conditions are fairly uniform over the working area.

3. The intensities of daylight should be such that artificial light will be required only during those portions of the day when it would naturally be considered necessary.

4. The windows should provide a quality of daylight which will avoid a glare due to the sun's rays and light from the sky shining directly into the eye, or where this does not prove to be the case at all parts of the day, window shades or other means should be available to make this end possible.

5. Ceilings and upper portions of walls should be maintained a light color to increase the effectiveness of the lighting facil-

ities from window areas. The lower portions of walls should be somewhat darker in tone to render the lighting restful to the eye. Factory green or other medium colors may be used to good effect.

11. *Classification.* Means for natural lighting may be classed under three broad divisions as follows:

(*a*) That case in which the windows are located on the sides of the building or in the framework of saw-tooth construction where diffused light from the sky reaches the work during a large portion of the day.

(*b*) That case in which windows are located overhead on a horizontal or nearly horizontal plane in the form of skylights, thus furnishing direct light from the sky during a large portion of the day.

(*c*) That case in which prismatic glass takes up the direct light from the sky and redirects it into the working space.

Method (*a*) is, of course, the most common of the three, and it may be noted that the saw-tooth or other roof-lighting constructions have become very popular and result in an excellent quality and quantity of light for given window areas, provided the size and location of windows are in accord with modern practice.

12. *Increasing the value of floor space.* Adequate and well distributed natural light means that certain portions of the floor space which ordinarily would not be available for work, are converted into valuable manufacturing space. In a general way, therefore, the average factory, mill or other work place, if properly designed, should possess natural lighting facilities which produce the best practicable distribution of daylight illumination.

13. *Wide aisles.* With low ceilings and very wide aisles, workmen located at the central portion of the building must sometimes depend for their natural light on windows located at a considerable distance away from their working position. In these cases it may be possible, in general, to depend altogether on daylight over an entire floor space, even at those times of the day when daylight conditions would be entirely adequate under other circumstances. This statement applies to side windows rather than to skylights or to saw-tooth construction. Fig. 1 illustrates this feature.

14. *Varying conditions.* In a case of this kind, employees located next to the windows are furnished with suitable daylight in the early morning and towards the latter part of the afternoon, the upper portions of the windows being particularly serviceable in lighting areas at some distance away from the windows. A southern exposure, however, results in such excessive light from the sky during the middle of the day, that heavy shades are nearly always pulled down so as to cover the

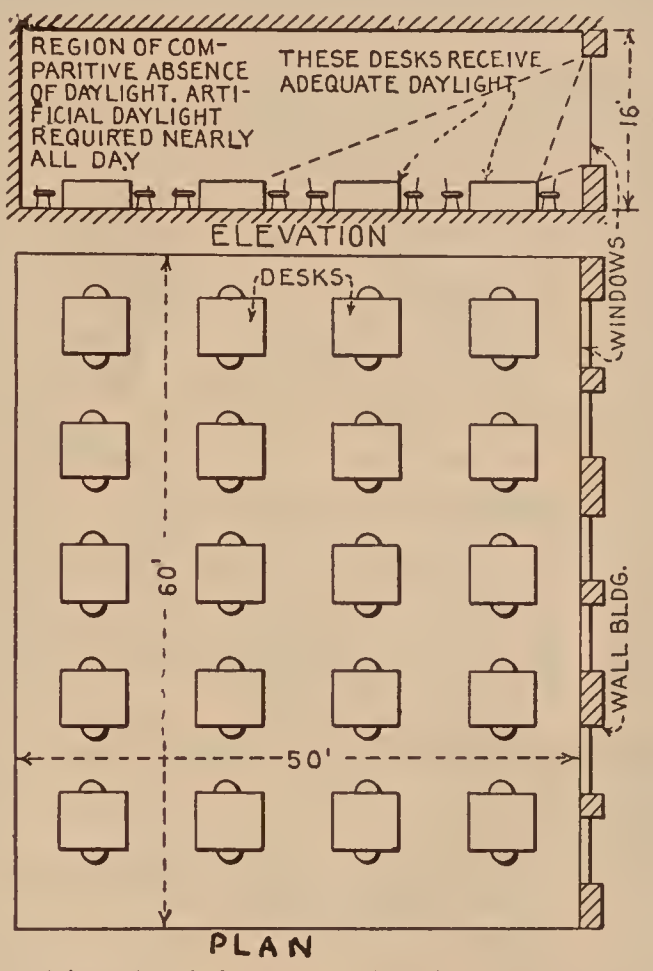


FIG. 1. Diagram of a large office with windows on one side only.

entire window area. This plan makes it necessary to use artificial light throughout the larger part of the office during the brightest portion of the day, and reduces the daylight at those points where it would supposedly be the best, namely, near the windows. Here the location of the windows is a large factor in the excellence of the daylight conditions, but the manipulation of the shades is perhaps even more important. To avoid such difficulty, adjustable translucent upper window shades with adjustable opaque lower shades might be employed.

15. *Upper portions of windows.* It should be further noted in this illustration that the upper portions of the windows give a reduced illumination in proportion to their areas, to the floor space near them. In rooms of moderate size, therefore, the

windows should be placed as near the ceiling as practicable. When the sun shines through windows so located, the direct light must be reduced or diffused. This may be accomplished by the use of ribbed glass in ordinary factory and mill buildings, and in offices by the use of translucent sunshades or awnings.

16. *Tempering the light.* The light due to the sunshine on such shades and awnings will be as bright as ordinary skylight if the shade is well chosen, and the ribbed glass will be still brighter. If the windows are large, the illumination is likely to be too great near the windows as previously pointed out and it should be reduced. This should not be done, however, by pulling down an opaque shade over the top of the windows because the top portion of the window is the part that is particularly needed to give light to the interior of the room. The better scheme is to employ an opaque shade which should be raised from the bottom of the window. This will reduce the illumination near the window without affecting it over the interior of the room to any marked degree.

17. *Bench locations.* Fig. 2 shows how benches are commonly located with respect to windows, so that the light received on the work may be most satisfactory. This sets a certain

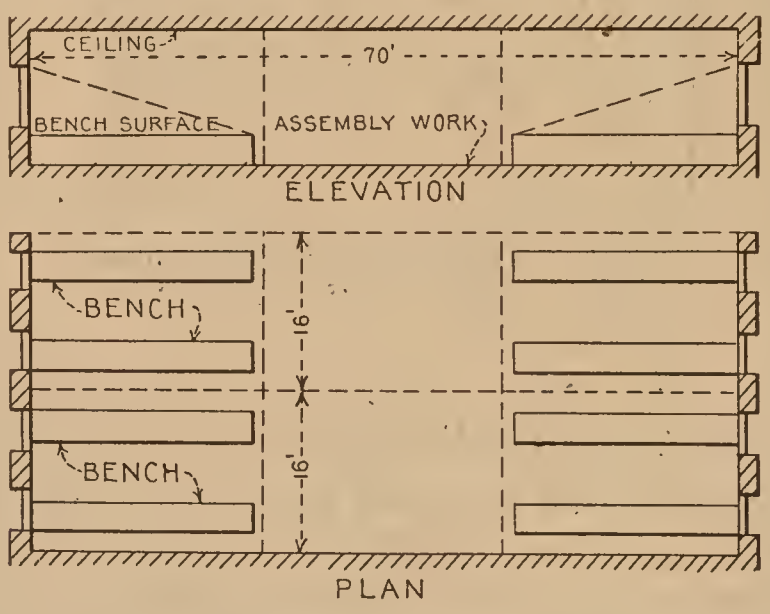


FIG. 2. Diagram showing benches located with respect to the windows so as to receive the natural light advantageously.

limitation upon the possible arrangement of the work over the floor space, depending on the way daylight is furnished to the floor area. This limitation can be eliminated almost completely in the case of artificial light through a uniform distribution of lamps overhead. This statement applies to those

cases where natural light is transmitted through side windows, and includes a feature specially noticeable in buildings of more than one story. In contrast, the work may be arranged almost independently of the natural light in buildings where the natural light is furnished by overhead windows or through the means of saw-tooth construction.

18. *Window glasses.* Both translucent and clear glass are employed for factory and mill windows. There is a slight reduction in the transmitted light through ordinary translucent wire glass, but it is often required by insurance regulations for a deduction in the fire risk where a given building is located in close proximity to other buildings. Wire glass is also used quite generally with steel window frames, here being an added protection from the standpoint of fire risk. Wire glass may be obtained in clear form, but its expense in contrast to the translucent form is such as ordinarily to prohibit its use for industrial purposes.

19. *Wire glass.* Wire glass, also known as ribbed glass, should be used and is advocated for practically all factory and mill windows where prisms are not required. Wires of rather open mesh cause so little reduction in light as to warrant no mention of this feature. Special care should be taken to get such glass as is smooth both on the flat side and on the ribbed side to facilitate cleaning. Wire or ribbed glass gives better diffusion than plain glass.

20. *Prism glass.* Where the sky outside of the windows is obstructed by buildings, prism glass is recommended if the room is deep. Different kinds of prisms can not be used to advantage interchangeably. The amount of prism glass required in any case depends much upon the surroundings and to obtain excellent results, of which such glass is capable, it must be used intelligently.

21. *Skylights.* Skylights are sometimes installed in long narrow continuous strips in a sloping roof. The ribs of the ribbed glass are generally so arranged that it is convenient to make them at right angles to the length of the strips. The result is that the sunshine is diffused by the ribs over a narrow area parallel to the strip of skylight, thus lighting one part of the room much more brilliantly than the remainder. If the ribs are installed to run parallel to the strips, they will give a much more general distribution of the sunlight. In the

foregoing, the word strip refers to the long belt of skylight and not to the individual sheet of glass. Ribbed glass in vertical windows should generally be placed with the ribs horizontal. They thus roughly fulfill some of the functions of prisms.

22. *Dirt accumulations.* While translucent wire or ribbed glass reduces the amount of light transmitted through the windows, the roughness of the outside surface of such glass often causes accumulations of dust and dirt, which are more to blame for the reduction of transmitted light in some cases than the translucent nature of the glass itself. Remedies of this difficulty are to secure smooth glass and to resort to frequent cleaning.

23. *Wire glass as a safeguard.* Wire glass for skylights is, of course, a practical necessity as a safeguard against accidents due to accidental breakage of the glass or due to objects falling on top of the glass.

24. *Sunshine not desirable.* In all the work of providing natural light, it should be kept in mind that direct sunshine in itself, from the illumination standpoint, but irrespective of sanitary conditions, is not wanted. The idea that sunshine is the important item is a common but an erroneous impression. For example, in saw-tooth construction, the windows do not face the south to get all the sunshine possible, but they face the north to exclude the sunshine. Ordinarily windows, on the other hand, face all directions because not enough light can be distributed to interiors from north windows alone. Windows on the other than north fronts admit sunshine to be sure, and this makes sun shades and awnings necessary to exclude the excessive brightness.

VALUE OF ADEQUATE ILLUMINATION.

25. Factory and mill owners are concerned in the matter of securing the largest output for a given manufacturing expense. An improved machine tool capable of increasing the product for given labor costs is most attractive, provided its first cost is within returnable limits out of the larger profits. Improved small tools, better methods of handling material, adequate crane service, fire protection, good shop floors, accurate and efficient timekeeping methods, and similar items, vitally concern the shop manager; money is expended to realize

excellence in these features because they afford increased economies and protection, thus resulting in a higher efficiency of the plant.

26. *Energy consumption a minor item.* Many arguments leading to the sale of gas and electric lamps for use in factory and mill buildings are based on reducing the lamp operation cost of substituting a new for an older system. Arguments of this kind are of value, however, only when such a reduction in operation cost can be effected without sacrifice in the adequacy of the illumination. It would be a poor policy, in the extreme, to argue a saving in energy consumption by the substitution of one type of lamp for another on a basis of equal candlepower in both old and new systems.

27. *Effect of good light on production.* Arguments of a convincing nature, which insure to the factory or mill manager an increased output through improved illumination service, are of importance and even greater at times than reductions in the cost of illumination for the same quantities of light. In view of the fact that resulting advantages of superior illumination on increased output are apt greatly to exceed economies in operation cost as regards the lighting system, it is a distinct advantage to direct and hold the attention on the former rather than on the latter. This statement will be more apparent when interpreted into definite items as follows:

28. *Advantages of good light.* While the necessity of good natural and artificial light is so evident that a list of its effects may seem commonplace, these same effects are of such great importance in their relation to factory and mill management, that they are well worth careful attention. The effects of good light, both natural and artificial, and of bright and cheerful interior surroundings, include the following items:

1. Reduction of accidents.
2. Greater accuracy in workmanship.
3. Increased production for the same labor cost.
4. Less eyestrain.
5. Promote better working and living conditions.
6. Greater contentment of the workmen.
7. More order and neatness in the plant.
8. Supervision of the men made easier.

In this list it will be noted that items 4, 5, 6, 7 and 8 all have a bearing on accident prevention.

29. *Interpreting the advantages of good light.* While the major consideration in the eyes of the factory or mill owner is undoubtedly and quite naturally the money value of good light in the larger return of both quantity and quality of work which may result from the installation of a superior as compared with an inferior lighting system, it should be noted that it is very difficult to interpret into dollars and cents the value of good light made possible by such returns. This difficulty is due to the necessity of keeping all conditions in a factory or mill section absolutely constant while varying the amount of illumination from poor to good conditions, in an effort to determine the output and its dependency on the light facilities. As accurate data becomes available, giving the increases in production for certain specific improvements in artificial lighting, it will doubtless prove helpful to a proper interpretation of adequate light and its worth to any plant.

The eight foregoing points are emphasized as forming the most important features in the problem of good lighting. Although difficult to interpret into money values, and somewhat intangible, they are indisputable arguments in favor of the best available illumination from the standpoint of the factory or mill owner.

30. *Practical example.* Continuing from the manufacturer's point of view, it may be said that certain assumptions as to energy cost, cleaning, interest and depreciation, show that the annual operation and maintenance cost for the illumination of a typical shop bay of 640 square feet area, may be taken at $50.00. If five workmen are employed in such a bay at an average wage of say 25 cents per hour, the gross wages of the men in such a bay, plus the cost of superintendence and indirect shop expense, may equal from $5,000 to $7,000 per annum. In a case of this kind, therefore, the lighting will cost from $\frac{7}{10}$ to 1 per cent of the wages, or the equivalent of less than 4 to 6 minutes per day. We may roughly say that a poor lighting system will cost at least one-half this amount (sometimes even more through the use of inefficient lamps and a poor arrangement of lamps), or the equivalent of say 2 to 3 minutes per day. Nearly all factories and mills have at least some artificial light, hence, in general, if good light enables a man

to do better or more work to the extent of from 2 to 3 minutes per day, the installation of good lighting will easily pay for the difference between good and bad light, through the time saved for the workmen.

31. *Actual losses.* Superintendents have stated in actual instances, that due to poor light their workmen have lost much time, sometimes as much as from one to two hours per day on certain days. If good light will add an average of say one-half an hour per day to the output, these 30 additional effective minutes represent an increase in output of 5 per cent, brought about through an expenditure equal to $\frac{1}{2}$ of 1 per cent of the wages for improved lighting, or a saving equal to ten times the expense.

OLD AND NEW LAMPS.

32. The inadequate means available for illumination by artificial methods in the past have contributed to the slowness of an appreciation of the features of artificial light which influence the working efficiency of the eye. Open flame gas burners, carbon incandescent and arc lamps, practically the only illuminants available ten years or so ago, play but a small part in the present approved methods of factory and mill lighting.

33. *New lamps.* The large variety of comparatively new lamps available for factory and mill lighting includes the mercury vapor, metallized filament, tungsten, gas-filled tungsten, metallic flame or magnetite arc, the flame carbon arc, the quartz mercury vapor, and various types of gas arc lamps. Remarkable improvements have thus been made in both the electric and gas lighting fields, the same general rules of applying the lamps covering both of these fields. Possibilities in factory and mill lighting are now attainable which, before the introduction of these new lamps, were either unthought of or impossible. Consideration of the eye as a delicate organ, together with the new ideas of the items which affect its comfort and efficiency, have resulted in establishing certain principles in illumination work, and have directed attention naturally and in a growing manner to the proper use and application of these new lamps.

EFFECTS ON FACTORY AND MILL LIGHTING PRODUCED BY MODERN LAMPS.

34. With the introduction of these new gas and electric lamps, broader possibilities have been presented in factory and mill lighting. The use of units of sizes adapted to the purposes, allows results which it has been hitherto impossible to obtain satisfactorily, either by the arc lamp, carbon filament or open flame gas burner, formerly available.

35. *New possibilities.* It is evident that the introduction of the many new lamps has made possible what may be termed a new era in industrial illumination, a distinctive feature of which is the scientific installation of the lighting units, suiting each to the location and class of work for which it is best adapted. Before the availability in recent years of medium sized gas and electric units the choice of the size of unit for a given location was often no choice at all. In many cases, due to small clearance between cranes and ceilings, or other conditions making it necessary to mount the lamps very high above the floor, but one size or type of unit was available, the carbon filament or open flame gas burner in the former, and the arc lamp in the latter case.

36. *Low ceilings.* For low ceilings, up to 18 feet, the use either of carbon filament, open flame gas burner, or arc lamps resulted usually in anything but uniform light over the working plane, and often produced merely a low general light which was practically useless for the individual machine. In such instances, individual lamps had to be placed over and close to the machines. With this arrangement, a relatively small area is lighted by each lamp and the metal shades usually employed serve only to accentuate the "spot lighting" effect. Such a form of illumination for factory and mill work is unsatisfactory and inefficient, but, as stated, was in the past in many cases the only available scheme. The absence of lamps of the proper size is no longer an excuse for the existence of such conditions in industrial plants.

GENERAL REQUIREMENTS OF ARTIFICIAL LIGHTING.

37. The following requirements for factory and mill lighting are made all the more important by the peculiar limitations and the wide variety of conditions to be found in factory and mill buildings and in factory and mill work:

1. Sufficient illumination should usually be provided for each workman irrespective of his position on the floor space.

2. The lamps should be installed and selected so as to avoid eyestrain to the workmen.

3. The lamps should be operated from sources of supply which will insure reliable illumination results, particularly on account of the demoralizing effect by intermittent service, just when the light may be most needed.

4. Adequate illumination should be provided from overhead lamps so that sharp shadows may be prevented as much as possible, and in such measure that individual lamps close to the work may be unnecessary except in special cases.

5. The type and size of lamp should be adapted to the particular ceiling height and class of work in question.

6. In addition to the illumination provided by overhead lamps, individual lamps should be placed close to the work if they are absolutely necessary in the eyes of a lighting expert, and in such cases the lamps should be provided with suitable opaque reflectors.

These requirements may now be met by means of the new types of gas and electric lamps, one type of which can usually be found for practically each factory and mill location, especially adapted to the general physical conditions of the location as typified by the clearance between cranes and ceiling and other similar items.

OVERHEAD AND SPECIFIC METHODS OF ARTIFICIAL LIGHTING.

38. Factory and mill lighting may be classified under two general divisions: First, distributed illumination furnished from lamps mounted overhead; and second, distributed illumination furnished by individual lamps located close to the work. For practical purposes this classification is sufficient. In numerous cases a combination of these two methods becomes necessary.

39. *Mounting the lamps high.* Where the lamps are high enough to be out of the line of ordinary vision, and are of a size and so spaced as to furnish illumination at any position on the floor where work may be carried on, the system is referred to as the overhead method of lighting. This method has many advantages. Its general adoption, which has been

somewhat slow, has increased with the appearance of the many new types of lamps and with the growing appreciation of the value of good lighting.

40. Where a small amount of general or overhead lighting is coupled with specific lighting from individual lamps, a large part of the floor space in many shops is in relative darkness, and much dependence must be placed on the hand lamps close to the work. The small number of overhead lamps generally used in such cases furnishes merely a small amount of additional illumination over the floor space which is not sufficient to be of much value. However, where sufficient intensity is provided by general illumination, this is often a very effective means of lighting a large workroom.

41. *Low ceiling.* Locations with low ceilings, until recently, have been lighted by the individual hand lamp method, because the old carbon filament lamps, being of low candlepower, could not well be used close to the ceiling, while the old type of arc lamp was often impracticable, due to its large physical size, as well as its relatively high candlepower. This statement is subject to some modification, because low candlepower units have sometimes been used in clusters for low ceilings as a compromise between a single small or a single large unit, this scheme being, however, usually insufficient and unsatisfactory in comparison with modern methods of lighting. In a particular manner, therefore, suitable illumination has been difficult with low ceilings.

42. New types of gas and electric lamps have a range of candlepower from very low to very high values, and the overhead system with the elimination of individual lamps is thus possible; in other words, a size of gas or electric lamp may now be selected from a large available list of sizes for nearly every factory or mill condition.

VARIOUS LOCATIONS ILLUSTRATED.*

43. Figs. 3 to 12 inclusive are given to indicate how the problem of adequate illumination has been solved in a number of actual instances, and the following notes apply to some of the considerations involved.

*Figs. 3 to 12 inclusive are, in general, arranged in the order of their mounting heights. The low mounting heights are shown in the earlier illustrations and the higher mountings in the later views.

There are two main items to consider in deciding for or against high candlepower lamps for the factory or mill. First, how high are the lamps to be mounted; and second, will the light at any given point on the machines or other operations be satisfactory if it comes from a few lamps or should it come from many sources? If the ceiling or overhead construction is under 16 feet, lamps of high candlepower can hardly be used in sufficient numbers to produce uniform illumination over the floor space. If they are to be mounted at a height between 16 and 25 feet, it is largely a question of whether light from a relatively few lamps will produce satisfactory results. For mounting heights over 25 feet, lamps of high candlepower possess some advantages, chief of which is their large volume of light for given energy consumed, always provided the light is effectively directed towards the floor.

44. *Three groupings.* These three groupings by mounting heights are conveniently shown in Figs. 15, 16, 17 and 18. In Fig. 15, a single shop bay with a ceiling height of 12 feet is shown as typical of the first grouping. The single high candlepower lamp furnishes approximately the same amount of light to the machines as do the eight small lamps. Note, however, that the illumination from the large lamp is not nearly as uniform as that from the small lamps, although the spacing of both the small and the large lamps as represented in this illustration is typical of many actual installations. Note also that the shadows cast by the large lamp at certain portions of the floor space must be so marked as to make the illumination it furnishes very inferior in this respect to the illumination from the smaller lamps, because of their larger number.

Here, if the number of large lamps for the given floor area be increased in an endeavor to make the illumination more uniform and to reduce the shadows, the expense as compared with that for smaller lamps, makes the large lamps a very unfavorable proposition. These two features are the basis for stating that in general large lamps are not desirable for mounting under 16 feet, and an analysis of conditions, together with a careful and unbiased comparison with the illumination produced by smaller lamps, will nearly always bear out this conclusion.

45. *Second grouping.* In Fig. 17, a 20-foot ceiling has been selected as typical of the second grouping, a single shop bay

being shown. Here the work is assumed to be rough assembly, mostly on horizontal surfaces, and the single high candlepower lamp, besides giving more nearly uniform illumination, because the light is distributed more broadly due to the increased height, is correspondingly more satisfactory as to shadows produced by the large lamp in the preceding illustration (Fig. 15), on account of the improved direction in which much of the light reaches the work. In this case, the arrangement of both large and small lamps is typical of many existing installations.

46. In Fig. 16, however, although the height is the same as in Fig. 17, the work is quite different, being conducted on the inside of large vertical tanks. It would obviously be impossible to perform this work by the light from the single large lamp as well as with that from the larger number of medium sized lamps, even if the actual amount of light from each was the same, on account of the poor direction of the light at certain positions of the work from a single unit in such a case. The medium sized lamps furnish approximately the same quantity of light and yet no matter where the tanks may be placed, they will receive considerable light from the medium sized lamps directly over or nearly over them, at least far more than is apt to reach them from a single unit in every other bay (the assumed arrangement of the large lamps).

47. For this second grouping of mounting heights, then, the large lamps may or may not be adapted, depending on whether the reduction of shadows is of much importance, as is the case in Fig. 16. The large lamp is, however, more likely to be satisfactory here than in the first case (Fig. 15), because of the better distribution of the light due to the higher mounting, a fact made evident in Figs. 15 and 17 on account of the decreased number of small lamps and the increase in their size made possible in Fig. 17 as compared with Fig. 15, where the mounting is lower. By the same line of argument, it can be shown that for higher mountings, large lamps are still more likely to prove satisfactory.

48. In Fig. 16, the number of large lamps might have been increased for the given floor area, but to have done so would mean that the cost for the energy and upkeep to maintain them would be excessive in comparison with the smaller types of lamps.

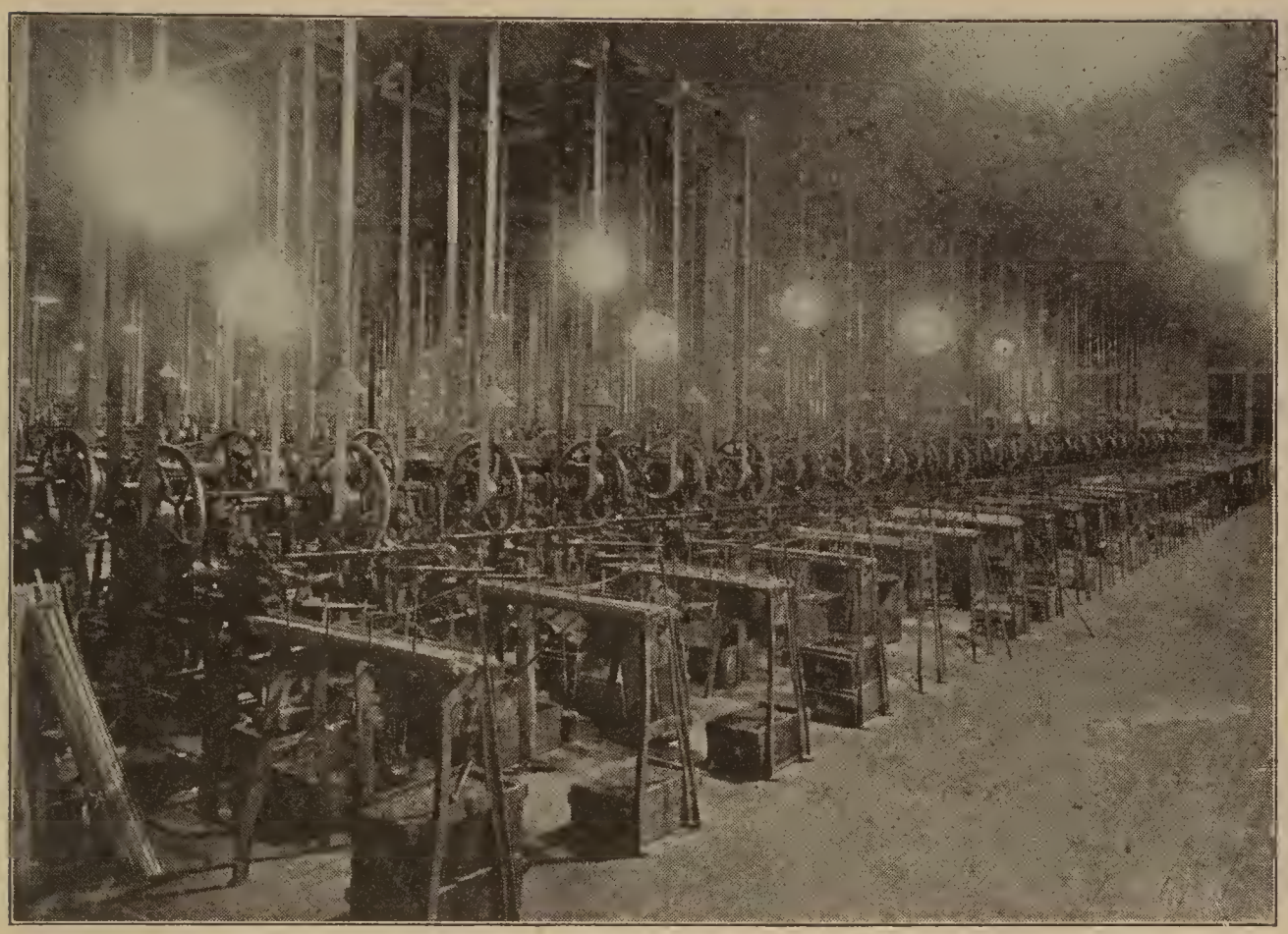


FIG. 3. Night view of a rather low factory section showing tungsten lamps of the 250-watt size mounted 12 feet above the floor. Note the original individual lamps over the machines.

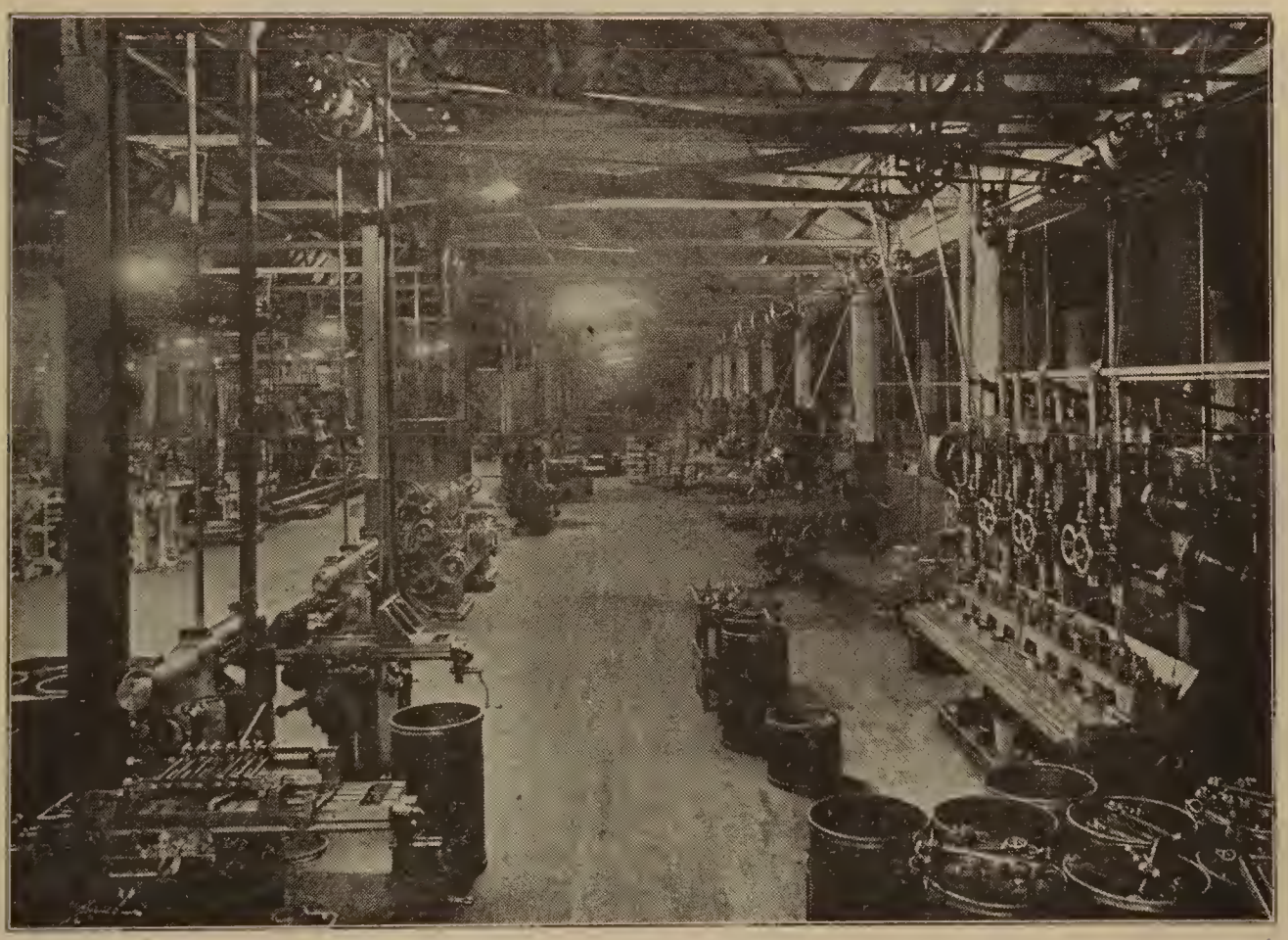


FIG. 4. Night view showing mercury-vapor lighting in low factory section. The lamps are about 12 feet above the work. Note the comparative absence of shadows.

FIG. 5. Day view of a gas lighting installation in a low factory section. This photograph shows merely the general arrangement of lamps and gives no idea of the illumination effect.

FIG. 6. Night view of a planing mill showing an installation of 250-watt tungsten lamps with a 16-foot mounting. Note the excellent distribution of the light and the comparative absence of shadows. This is an example of the overhead method of lighting.

FIG. 7. Night view of a boiler shop.

FIG. 8. Day view showing arrangement of gas lamps in a medium high factory space. Note the pierced reflectors over the machine tools near the center of the picture.

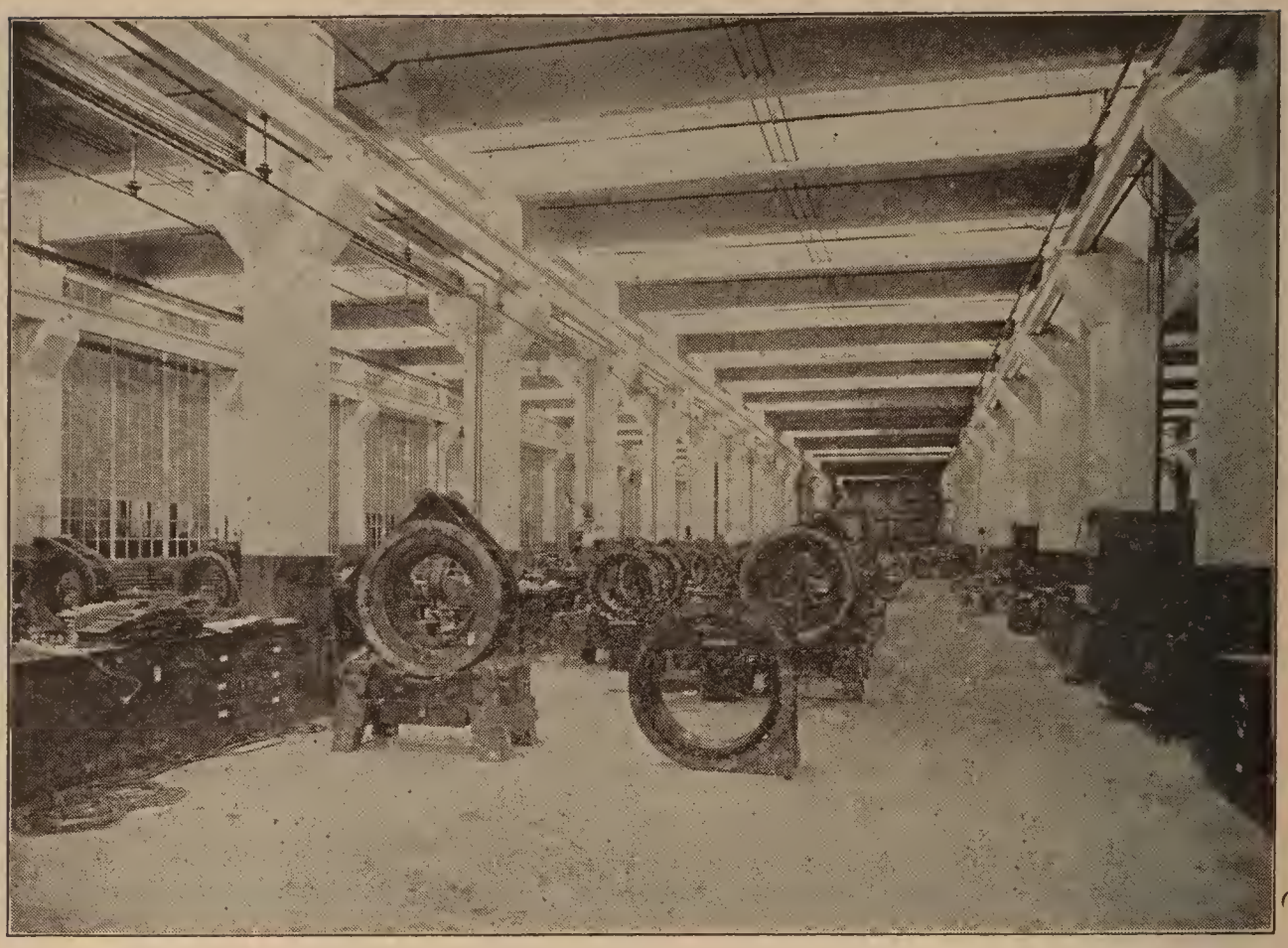


FIG. 9. Night view of factory section with relatively high mounting of 250-watt tungsten lamps. The lamps are 20 feet above the floor. Note the excellent distribution of the light and the shielding effect of the girders which serve to reduce the glare as one looks down the aisle.

FIG. 10. Night view of arc lamp installation with 40-foot mounting at center of picture and 20-foot at sides. Excellent distribution.

FIG. 11. Day view of relatively high section, showing a system of gas lighting.

FIG. 12. High section showing a system of mercury-vapor lamps. Note the excellent distribution of light over the floor area.

FIG. 13. Excessively bad lighting. Bare lamps produce a glare which is harmful and renders the illumination very ineffective. Compare with Fig. 14.

FIG. 14. Example of good tungsten lighting with metal reflectors. Note the row of lamps near the ceiling for producing general illumination. This is known as combined general and localized illumination. Compare with Fig. 13.

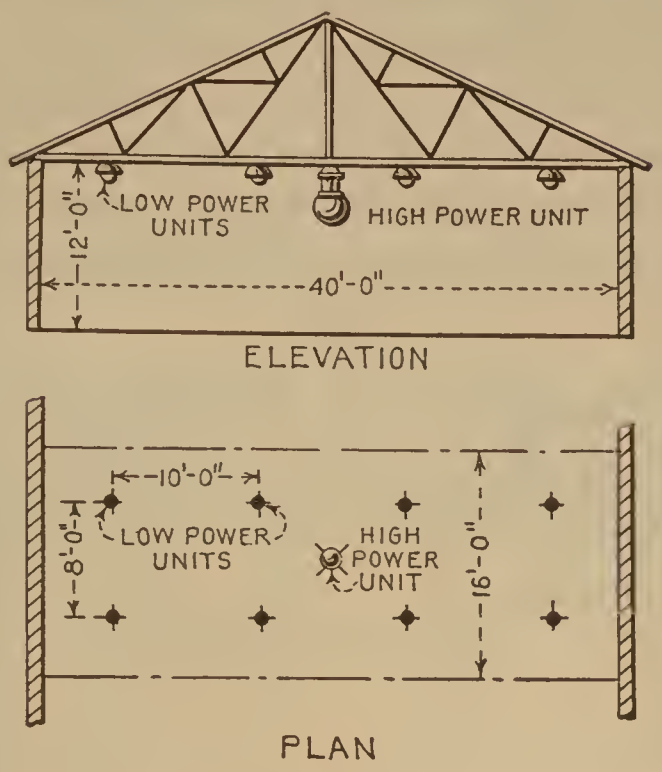


FIG. 15. Diagram showing alternate schemes for lighting a low factory section. This contrasts the use of large and small lamps for a mounting height of 12 feet.

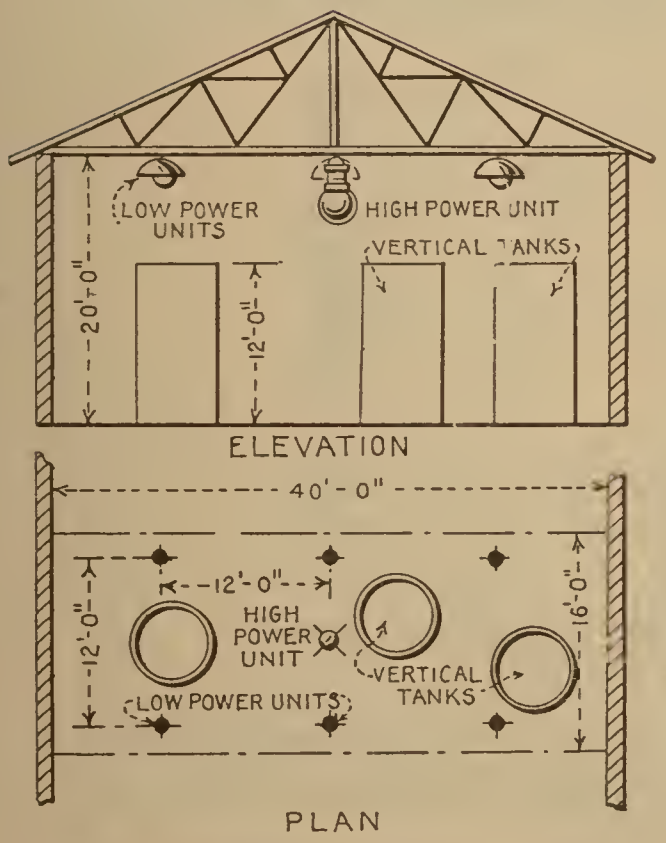


FIG. 16. Diagram contrasting the use of large and medium size lamps for mounting height of 20 feet.

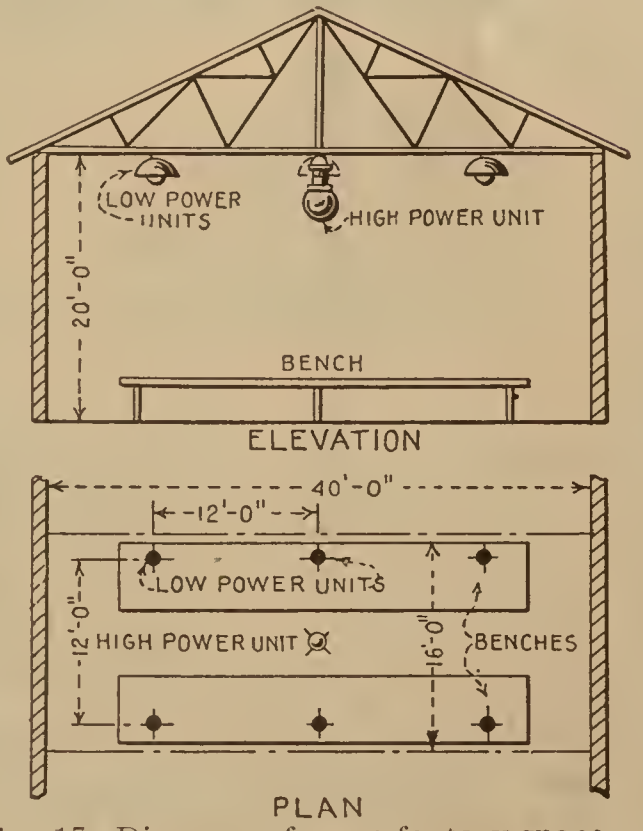


FIG. 17. Diagram of same factory space shown in Fig. 16, but with a different class of work. This view contrasts the use of large and medium sized lamps for a 20-foot mounting.

49. *Third grouping.* In Fig. 18, the third grouping of mounting heights is shown with the lamps about 50 feet above the floor. In this illustration the distribution of the light from the large lamps will be far more satisfactory, both for flat and tall work than in the two preceding cases. It will be noted further that the increased height of the lamp causes the light to fall in such directions as to distribute it evenly over

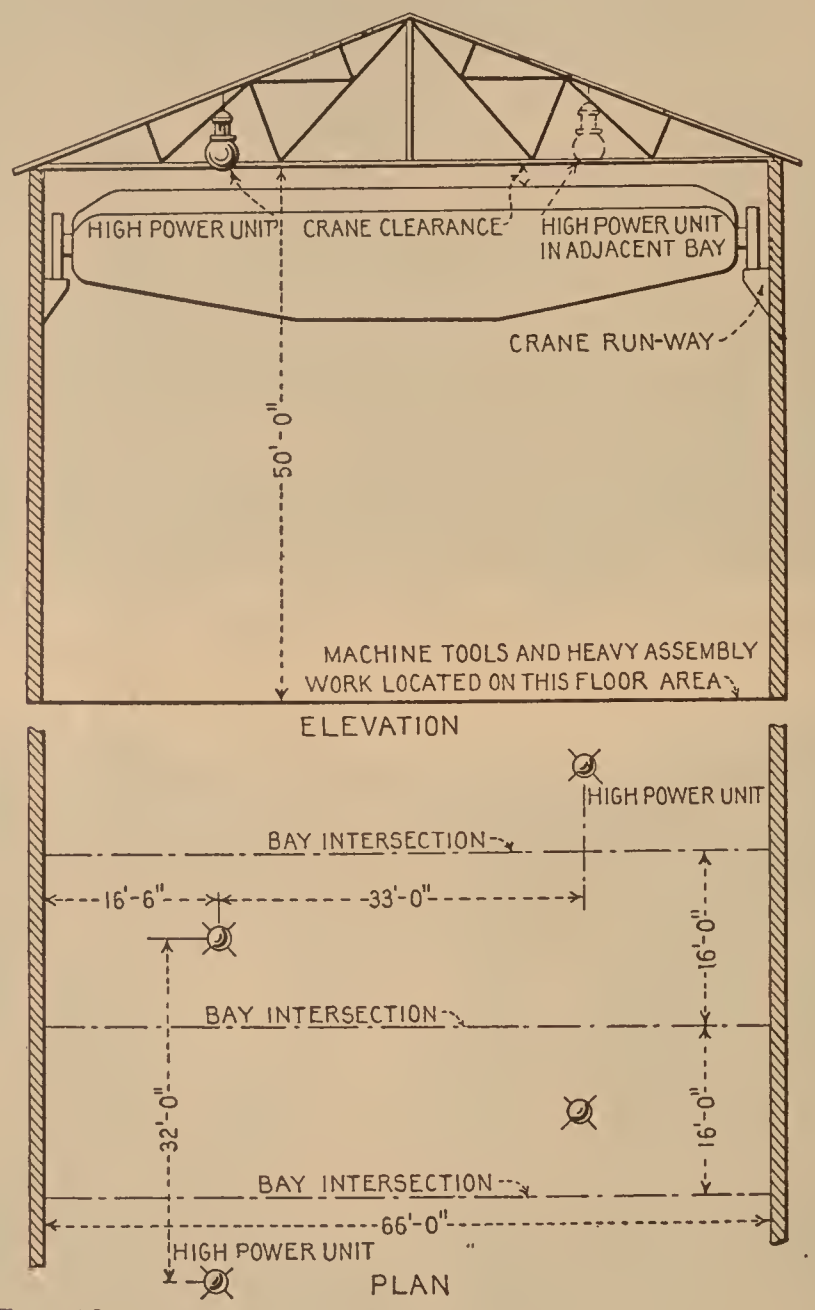


FIG. 18. Diagram showing the use of large lamps for a mounting height of 50 feet.

the entire floor space taken care of by this one lamp in much better shape than for the lower mounting heights. (See also Figs. 19 to 23, inclusive.)

LIGHTING CIRCUITS FOR ELECTRIC LAMPS AND SUPPLY MAINS FOR GAS LAMPS.

50. The question of lighting circuits is mentioned here with particular reference to factory and mill conditions, where motor loads are apt to be large in comparison to the energy

consumption of electric lamps which are in service. In some cases, the proportion of motor load to lighting load is in the ratio of 10 to 1, in others 7 to 1, and so on, and the varying demands on the circuits by motors may greatly affect the lamps. Hence it is important to maintain strictly separate supply circuits for the lamps in order to avoid varying voltage which is apt to result if the motors are connected to the same circuits with the lamps.

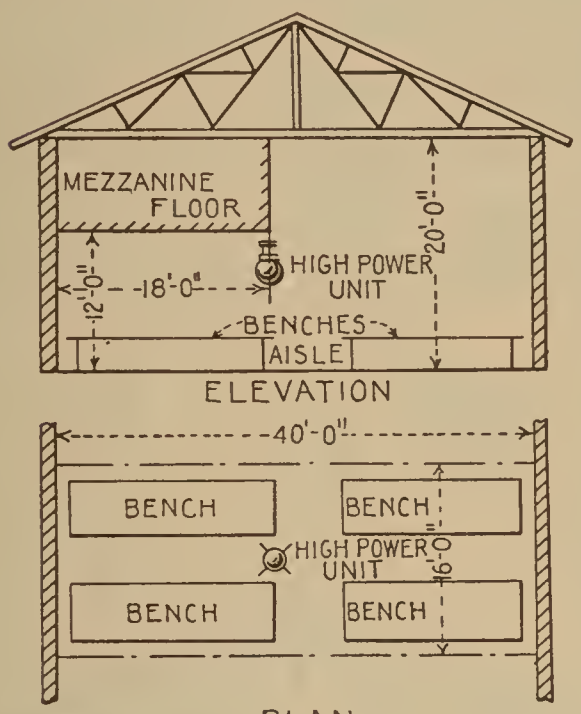


FIG. 19. This shows a very poor arrangement of artificial lighting by means of large lamps mounted too close to the floor. Compare this poor lighting scheme with the improved plan in Fig. 20.

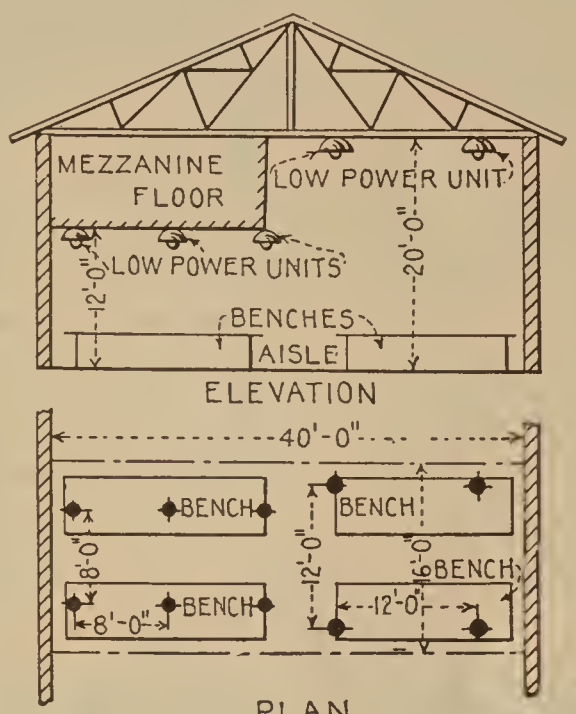


FIG. 20. This illustration is to be compared with Fig. 19. It indicates an improved scheme over that shown in Fig. 19; made possible by the use of smaller lamps.

51. *Constant voltage.* In addition to the superior illumination resulting from lamps supplied from constant voltage mains, some types operate with longer life or very much better mechanically when supplied with constant voltage than otherwise. These features will therefore generally more than offset the somewhat greater cost of maintaining separate circuits for each class of service. In like manner and for similar reasons, it is advisable to place gas lamps on supply lines separate from those delivering gas for power purposes.

CONTROL OF LAMPS AND ARRANGEMENT OF SWITCHES.

52. The control of lamps in factory and mill lighting is important in all cases, but specially so where a large number of lamps is used in preference to a small number for a given

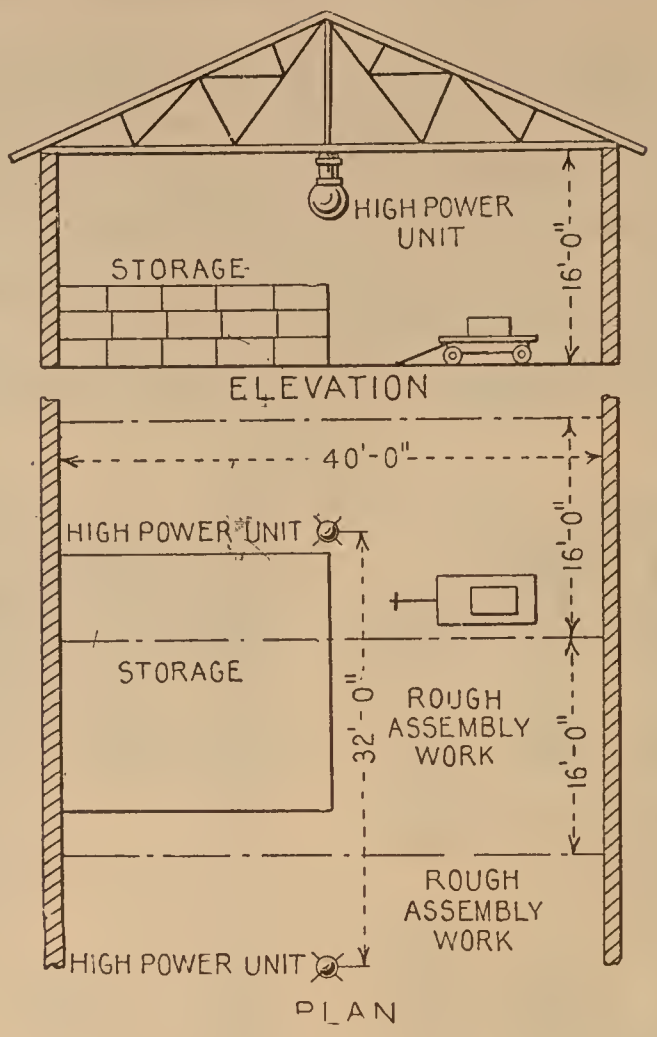


FIG. 21.

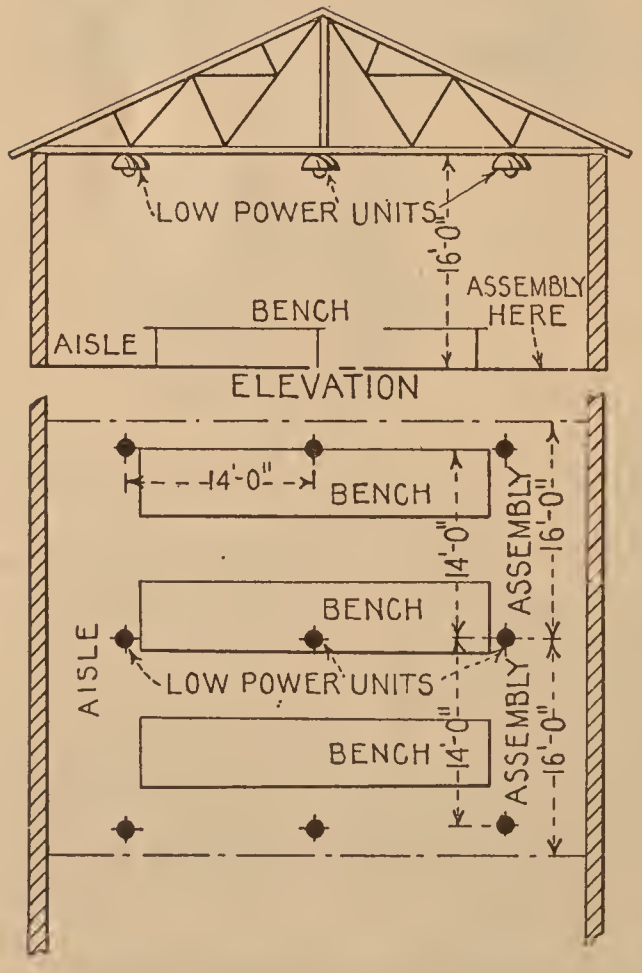


FIG. 22.

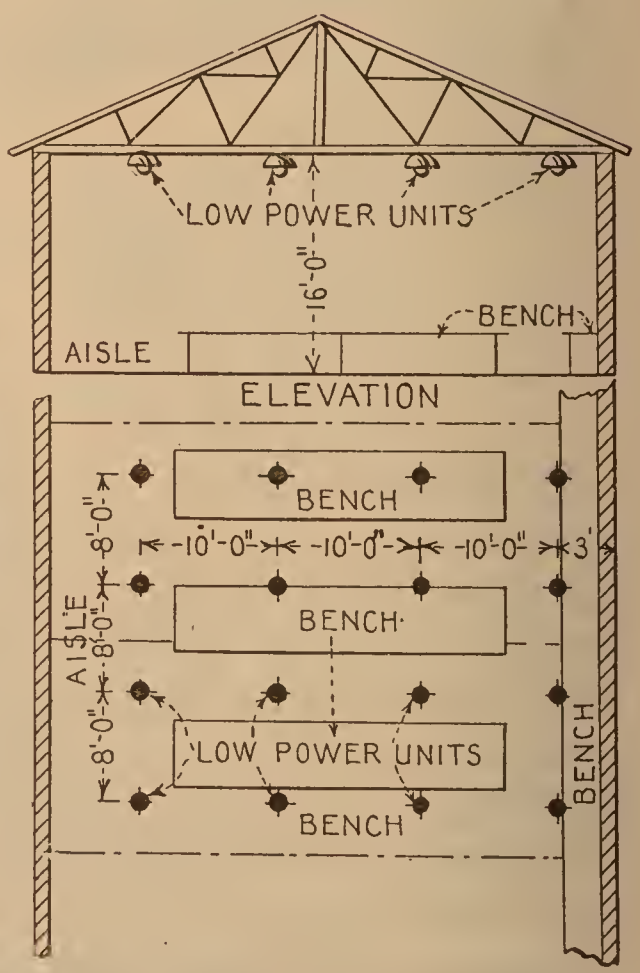


FIG. 23.

These three illustrations show various ways in which a factory space of 16 ft. girder clearance can be handled, depending on the class of work performed. The first case, Fig. 21, is fairly satisfactory for storage spaces, and either the second or third cases, Figs. 22 or 23, can be employed for bench assembly or manufacturing. The third case, Fig. 23, is to be preferred where the class of work consists of the handling of small machinery parts.

floor area. For example, where an overhead system of tungsten lamps of small size is used, a large number will, of course, be necessary for a given floor area, and in such cases the number of control circuits may at times seem excessive when planned out for sufficient flexibility of operation. Such circuits, however, in rendering the system more flexible, will be more than paid for by the saving in energy and maintenance due to the turning out of lamps not needed in certain sections of the factory or mill, provided the number of hours per day during which the lamps are used on the average is relatively large, and the differences in daylight intensities over the floor area is also relatively large.

53. *Control parallel to windows.* The lamps most distant from the windows will usually be required at times when the natural light near the windows is entirely adequate, thus making it an advantage to arrange the groups of lamps in circuits parallel to the windows. The advantages of this method are further apparent when it is considered that if the lamps are controlled in rows perpendicular to the windows, all lamps in a row will necessarily be on at one time, while a portion only may be required.

54. *Practical case.* The foregoing statement may be developed into a definite proposition. Thus, to install a single switch may involve say $5.00 as its first cost. If ten lamps are to be controlled from a single switch, these ten lamps must obviously either all be turned off at a time or all turned on at a time. An additional switch at a cost of $5.00 will permit either half of these ten lamps being turned off, if not required at certain times when the remaining five are needed. This extra switch may or may not be an economy. Consider, for example, the case where these five lamps are of the 60-watt tungsten type, and that they are turned off by the extra switch on an average of one-half an hour per day while the others are needed, or vice versa. In a year's time, the energy saved at 1 cent per kilowatt-hour, will amount to perhaps 50 cents. At this rate it will require ten years for the energy saved to pay for the first cost of the extra switch. This would not be considered a distinct economy. If, however, the energy cost be greater, and more nearly the average under actual conditions, or if the number of hours per day during which a

portion only of the lamps will not be used, be greater, then these values will be correspondingly modified.

55. *Locating switches and controls.* In locating switches or controls in factory and mill aisles, care should be exercised to arrange them systematically, that is, on columns situated on the same side of the aisle and on the same relative side of each column. This plan materially simplifies the finding of switches or controls, by those responsible for turning on and off the lamps, and is particularly important where a given floor space is illuminated by a large number of small or medium sized lamps distributed uniformly over the ceiling area, a feature which is usually accompanied by the use of a relatively large number of switches or controls.

SYSTEMATIC PROCEDURE SHOULD BE FOLLOWED IN CHANGING A POOR LIGHTING SYSTEM OVER TO AN IMPROVED ARRANGEMENT.

56. When undertaking the change from an old to a new lighting system, the various forms of illumination which are adapted to factory and mill spaces should be studied, and an investigation made of the various types of gas and electric lamps on the market which are available for the purpose.

57. Time should be allowed for a study of the given locations to be lighted; for preparing the plans of procedure in the installation of the gas or electric lamps and auxiliaries; and for customary delays in the receipt of the necessary supplies and accessories to the work in hand. Altogether, therefore, work of this kind requires considerable time for its completion.

58. *Using the shop force.* In large factories or mills, a wiring or gas-fitting force is sometimes a part of the maintenance division. The work of the wiremen or fitters is likely to be heaviest in the winter, due to the dark days. Where this condition exists, there is all the more reason to apportion out new work so as to accomplish it during the months of least wiring and piping repair activity, and further, at that time of the year when employees will be comparatively unaffected by the disturbances usually associated with a change from an old to a new lighting system through possible irregularities in the illumination service while the wiremen or fitters are at work.

59. *Distribution of expense.* Another feature different from the foregoing viewpoint is in the distribution of the installation cost over a relatively long interval. If, for example, the system is desired for the approaching winter, the complete wiring or piping plans may be drawn up and blocked out into three, four or even more sections, thus spreading the expense over as many months.

60. *Yearly appropriation.* In some shops a given appropriation may be allotted each year for building equipment. From the standpoint of finance plans, it may thus be desirable to distribute outlays of this nature over the year, rather than to concentrate them at any one time. An important consideration in this method of installing lamps, however, is to prepare in as far as possible the complete plans in advance, at least as regards given factory or mill sections, so as to insure a uniform and symmetrical installation as a whole when the component parts are finished.

REFLECTORS AND THEIR EFFECT ON EFFICIENCY.

61. A reflector or shade is used in conjunction with a lamp for the purpose of reducing the glare otherwise caused by looking directly into the bare lamp, as well as for the purpose of redirecting the light most effectively to the work.

62. Reflectors and shades, both metal and glass, are now obtainable for each size of incandescent electric and gas lamp. For a certain ratio between the spacing and the height of the lamps, a reflector can nearly always be selected which will furnish uniform illumination over the working surface.

63. *Function of reflector.* Owing to the direction of the light from the lamp, nearly all types of lamps, in addition to the downward light, furnish some rays which go upwards and away in other directions from the objects to be illuminated, and are therefore relatively not useful. Furthermore, a bright source in the field of vision causes an involuntary contraction of the pupil of the eye, which is equivalent to a decrease in illumination in so far as the eye is concerned. Hence, while reflectors or shades may at first seem to reduce the amount of light in the upper part of the room, their use actually increases the amount of light in a downward useful direction, and improves the "seeing," due to the better conditions which surround the eyes. The economic function of

the reflector as contrasted to this easier condition it affords the eyes, is to intercept the otherwise useless or comparatively useless rays which do not ordinarily reach the work, and to reflect them in a useful direction. In performing this function, there is a choice through the design of the reflector, in the manner of distributing the light, so as to make the illumination on the floor space uniform with certain spacing distances and mounting heights as previously mentioned.

64. *Avoiding dark spots.* With the use of lamps for which a large variety of reflectors is available, the proper reflector should therefore be chosen so as to give the desired distribution of light. In other cases, as in the use of the gas or electric arc lamps, where the globe or reflector is usually a fixed part of the lamp, care must be exercised to space the lamps at sufficiently close intervals to insure uniformity of the illumination, that is, a freedom from the relatively dark spaces which exist between lamps when spaced too far apart.

65. *Light interiors.* With a light ceiling, the reflection of that part of the light which passes through a glass reflector to the ceiling, and which is added to the light thrown downward from the under surface of the reflector, is a factor in building up the intensity of the illumination on the working surface. Great importance is therefore attached to light interior colors, especially on ceilings and the upper portions of walls, both in reinforcing the direct illumination, and in giving diffusion, which in turn adds to the amount of light received on the side of a piece of work. It should also be stated that the intensity of the light from bare overhead lamps when measured on the working surface may be increased by as much as 60 per cent through the use of efficient reflectors. This is due to the utilization of the horizontal rays of light as previously stated, which predominate in the bare lamp, whereas the most effective light in factory and mill work is apt to be that which is directed downward.

66. *Points to consider.* Reflectors will not be classified here from the commercial standpoint, but the following items should be given consideration in the selection of the type of reflector for factory or mill use:

1. *Utilization efficiency.* How much does the reflector contribute to the effective illumination on the work?
2. The effect in reducing glare.

3. Natural deterioration with age through accumulations of dust and dirt.

4. Ease in handling and uniformity of manufacture.

5. Physical strength and the absence of projections which may increase the breakage in case of glass reflectors.

67. A study of the various reflectors on the market with the aid of these items as a basis will determine what reflectors are best adapted to given conditions. Regarding the third item in the foregoing list, it may be stated that under comparative tests in service, the accumulations of dust and dirt on glass reflectors do not seem to be any greater than the coating of dirt which accumulates on the inside of a metal reflector in the same length of time.

SIDE LIGHT IMPORTANT IN SOME FACTORY AND MILL OPERATIONS.

68. It has been customary in many cases to measure the effectiveness of illumination in terms of the vertically downward component of the light. This method has ignored the value of side components in relation to vertical surfaces and openings in the side of the work. It is sometimes more necessary to light the side of the machine or the side of a piece of work than the horizontal surface. If, then, in designing a factory or mill lighting system, the prime object is the production of the greatest amount of downward illumination, it may happen that the side component is so small that the sides of machinery or of work are inadequately lighted.

69. *Two ways to secure side lights.* Experience indicates that there are two general ways in which to secure adequate side lighting. One of these methods is to lower the lamps, and the other is to use broader distributing reflectors than are called for by the rules which consider uniformity of the downward illumination only. Side walls or other reflecting surfaces will modify the results. Thus, after the determination of a certain type of reflector for producing uniform vertically downward illumination, it may be found that more side light is necessary, and this extra side component may, as stated, usually be secured by selecting a somewhat more distributing reflector. Broader distributing reflectors are apt to result in less downward illumination and will sometimes call for larger lamps than found necessary by preliminary calculations.

70. *Practical case.* As an illustration, in a certain lighting system a vertically downward intensity of about 3 foot-candles was deemed sufficient for the work involved. Measurements and observations showed that the side light was insufficient. In this particular installation it was found necessary to produce a vertically downward intensity of about 5 foot-candles on the average in order to secure an intensity of about 2 foot-candles on the side of the work, and also to use a somewhat broader distributing reflector than at first chosen. Two foot-candles on the sides of the work were sufficient in this case where bench work and work in the vise on small machine parts were conducted.

71. *Keeping the lamps high.* It is recommended that the lamps be mounted near the ceiling in all reasonable cases where side light is necessary, and that the side light be increased, not by lowering the lamps, but through the medium of broader distributing reflectors and larger lamps, if required. This attitude is taken on account of the glare which results when lamps are mounted too close to the work, a feature most noticeable in the absence of a reflector or where glass reflectors are used.

72. *Maintenance.* Provision should be made for systematic upkeep of natural and artificial lighting.

73. *Windows.* Factory and mill windows become covered in time with dirt, and produce greatly decreased values of natural light in consequence. These losses may easily be great enough to affect the workmen seriously, and to necessitate the use of artificial light at times when otherwise it would not be required. Dark surroundings also increase the likelihood of accidents. Regular window cleaning should therefore be a part of the routine of every factory and mill building or group of buildings.

74. *Lamps.* Carbon filament, mercury-vapor, gas mantle and tungsten lamps burn out or break, globes and reflectors become soiled, and the various other items of deterioration take place so gradually that in many cases they are given no special concern in the practical economy of the shop. Moreover, it is hardly necessary to mention the fact that often lighting systems are allowed to deteriorate to an extreme point and nothing is done unless complaints come in from employees after the lighting facilities here and there throughout the shop

have become so poor that work has to be discontinued temporarily. The losses of time from such circumstances, when added up throughout a year, are more than likely to exceed the expense of systematic attention to such maintenance items in advance.

75. *Overhead system.* Furthermore, with modern methods where the lamps are usually mounted overhead rather than close to each machine, the importance of relieving the workmen from any care of the lamps, and placing it in the hands of a maintenance department is even greater than has been the case in the past, particularly in large plants.

76. *Reflector cleaning.* The serious loss of light when globes and reflectors are allowed to go for long periods without cleaning is shown in Fig. 25. This set of curves resulted from a test on a glass reflector used with a tungsten lamp. The one curve shows the value of the light given by the lamp at different angles when the lamp and reflector are clean, while the smaller curve shows the enormous reduction of light after the lamp and reflector have been in service for about four months without being cleaned.

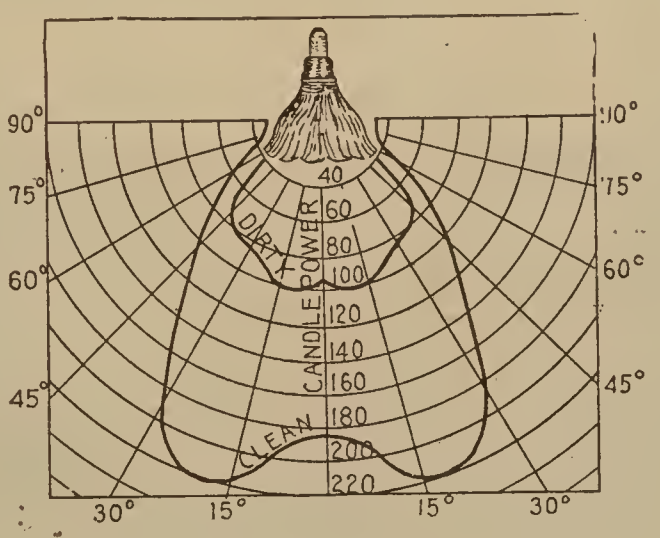


FIG. 25. Curves showing serious losses of light from a tungsten lamp and its reflector, due to accumulations of dirt. This is a condition applicable to all types of lamps, as other illuminants suffer corresponding losses from dirt accumulations.

77. In this particular case, which is a typical one, the loss of light at the end of the four-month interval amounted to about 50 per cent. The cost of electrical energy in this shop was such that the loss of light during the fourth month,

FIG. 26. Very poor lighting in a worsted goods factory. The wiring is badly arranged, the contrasts between light and dark portions of the room are excessive, and in some cases the wrong size of lamp is used in a given reflector. The system is unsightly and represents bad practice. Compare with Fig. 27.

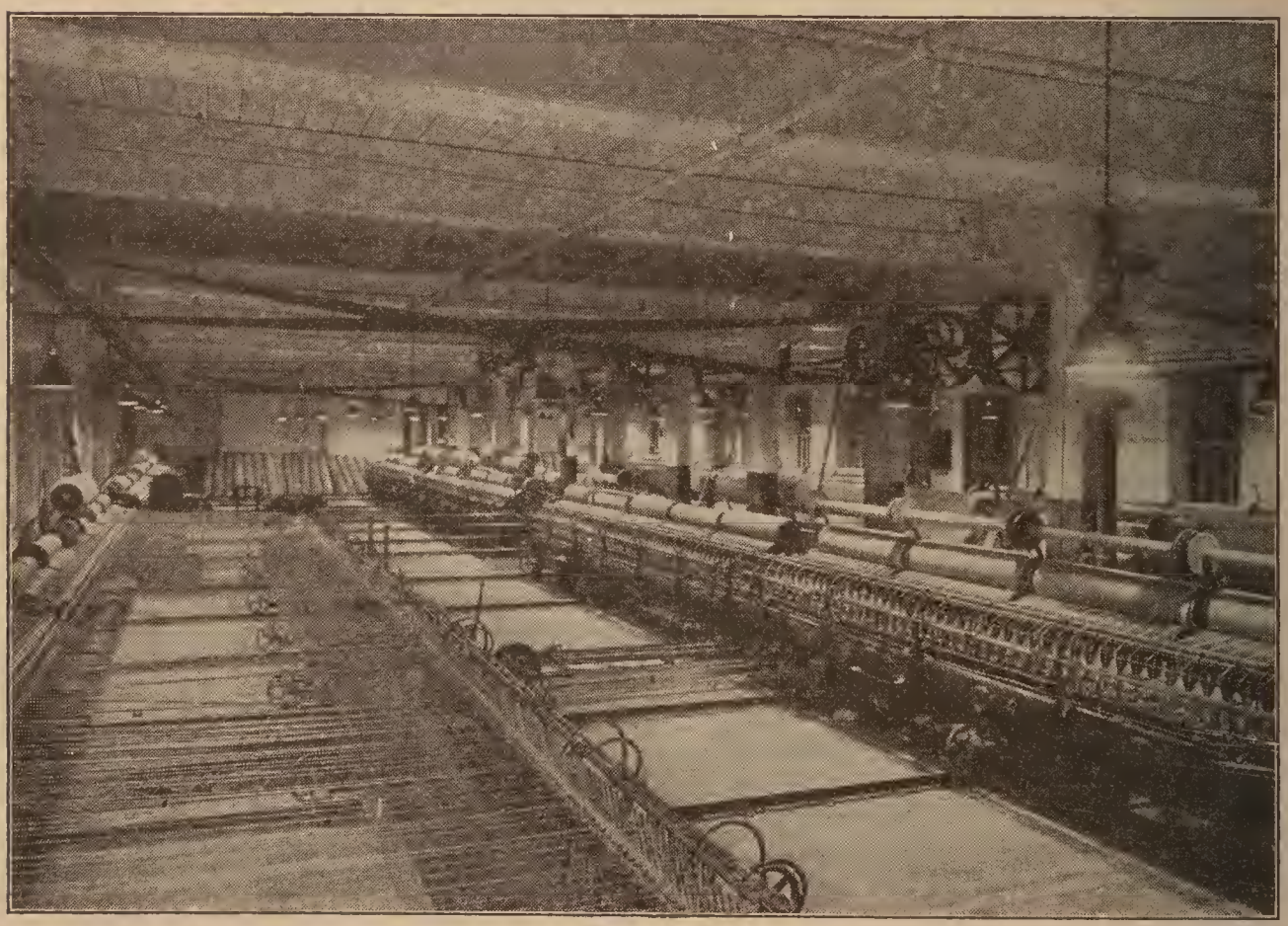


FIG. 27. Worsted mill with localized general illumination. This is an example of excellent illumination with tungsten and metal reflectors. Note the reflection from the goods to the ceiling. Compare with Fig. 26.

FIG. 28. Very poor arrangement of arc lamps. The lamps are mounted to one side of aisle over line shafting. Very little light reaches the machinery to the right. Compare with Fig. 29.

FIG. 29. Well planned system of arc lighting. The lamps are high and above the ordinary line of vision. Compare with Fig. 28.

amounted to about 12 cents, while the total cost of taking down, washing and replacing this reflector amounted to about 3 cents. The economy of a fairly frequent attention to cleaning of such reflectors is at once apparent, even if the improved condition of the light in itself be ignored.

78. The example just given will serve to illustrate the class of upkeep problems which are involved in shop lighting. The most forcible emphasis is applicable to the idea that system may properly be called a first step towards success in this line of maintenance work.

79. *A method of inspection and maintenance.* In one large factory a regularly developed method of inspection and renewals is employed. As an example, the method as applied to several thousand tungsten lamps which are in service in the various buildings will be described. All the lamps are inspected once per day, except Saturday and Sunday. A regular route is followed by the inspector, and all burned out lamps, broken switches, loose fuses, and similar items are noted. Careful observation is also made of reflectors which appear to need washing and any other points which might affect the efficiency of the system, after which a report is made up about noon and promptly sent to the maintenance department to permit all renewals and repairs to be made before night. In this manner the lamps are well maintained from day to day.

80. *Marking columns.* To facilitate this renewal work, it has been found advantageous to mark all columns through this shop. The inspector is thus enabled to indicate clearly the location of each burned out lamp and the renewal man to locate it without delay. It is helpful now and then in like manner to have the inspector note the unnecessary lamps found burning when artificial light is not required. If lamps are found burning at such times, a note sent to the head of the department calling attention to the matter, is usually sufficient to remedy the difficulty.

81. *Noting soiled reflectors.* As a check on a regular cleaning schedule the inspector should note all reflectors in need of cleaning. The frequency of each cleaning will depend on the rate of deterioration due to the settlement of dirt on the surface of the glass or metal and also on the surface of lamps, and the fact should be kept in mind that the amount of dirt on a reflector is nearly always deceptive, that is,

reflectors which have suffered a large deterioration in efficiency due to dirt often appear fairly clean, and for this reason it is best to increase the frequency of cleaning somewhat over that which seems sufficient from observation, particularly in view of the fact that tests indicate large reductions of light from apparently small accumulations of dust and dirt.

82. *A method of washing.* In the factory just referred to, all reflectors are removed to a central washing point. Where the number of reflectors to be hauled is large, a truck is used. Often, however, where only a small number of reflectors is to be transported, small hand racks, devised for the purpose, are employed. When an installation is in need of washing, the scheme is to haul sufficient clean reflectors to the location in question. The soiled reflectors are then taken down and clean ones immediately put into place, after which the soiled reflectors are removed to the central washing point, washed and put into stock for the next location.

EXPERT ASSISTANCE SUGGESTED.

83. The advantages of securing expert assistance in dealing with illumination are strongly emphasized. The points which come up for solution are complex and require, in many cases, the judgment of one who has had wide experience in the lighting field.

OTHER FEATURES OF EYE PROTECTION.

84. Care is urged on the part of those responsible for the health and welfare of employees to see that adequate eye protection is afforded in all operations which are apt to cause injury to eyesight if such protection is neglected. As typical of such other causes of danger to eyesight, arc welding may be mentioned, where the operator, according to accepted practice, must wear a helmet in general. Protective glasses for this purpose should not be judged as to their protective properties by mere visual inspection. They should, therefore, be analyzed for their spectral transmission of invisible radiation. Protective measures should also be taken to prevent onlookers from being unduly exposed to such eye dangers, by enclosing the welding operations with suitable partitions. These general remarks apply with equal force from the standpoint of those handling the operations to such other cases as the testing of arc lamps, inspection of hot metal and similar cases.

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GOOD AND BAD LIGHTING COMPARED.

85. In order to give an idea of good and bad lighting, Figs. 13, 14, 26, 27, 28 and 29 are shown. These illustrations indicate the use of various types of lamps and a reference to the captions under the illustrations will bring out the weak points of the poorly lighted spaces, as well as the points of excellence in those cases which are designed in conformity with good illumination practice.

METHOD OF MEASURING SURFACE BRIGHTNESS.

86. The candlepower of the brightest square inch of light source may be measured by means of a portable photometer. An opaque board with a square or circular hole one square inch in area is placed against the surface of the light source in such a position that the brightest spot emits light through the hole in the board. The board must be of such size as to prevent any other light from the source to strike the photometer. The photometer is placed at some convenient distance from the light source unit and read, care being taken to exclude all light from the photometer except that coming through the hole. If the photometer is read at a distance of one foot from the light source, the foot-candles observed will also be the candlepower; if the photometer is two feet distant from the light source, the foot-candles observed must be multiplied by four to obtain the candlepower; if three feet, they must be multiplied by nine, etc., the observed foot-candles in all cases being multiplied by the square of the distance between the light source and the photometer, when the readings were taken to obtain the candlepower of the source.

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